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REPRODUCTIVE DYNAMICS OF *METAPENAEUS AFFINIS* IN MUMBAI WATERS

Thesis submitted in partial fulfillment of the requirements for the degree of

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CERTIFICATE

Certified that the thesis entitled **"REPRODUCTIVE DYNAMICS OF *METAPENAEUS AFFINIS* IN MUMBAI WATERS"** is a record of independent bonafide research work carried out by **Ms K. Leena** during the period of study from November 1998 to November 2002 under our supervision and guidance for the degree of Doctor of Philosophy (Mariculture) and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar title.

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सारांश

दिसम्बर 1999 से नवम्बर 2000 की अवधि में मुंबई के समुद्री जल में *मेटापिनियस ऑफिनिस* (H. Milne Edwards) के पुनरुत्पादक गतिकी पर अनुसंधान कार्य किया गया । मात्स्यिकी क्षेत्र से उथले किनारे के निकट (गहराई 5-10 मी) किनारे के निकट (15-40 मी) और किनारे से दूर (70 मी तक) से मात्स्यिकी आंकडों के लिए योजित झींगों के नमूनों का विश्लेषण किया गया। नर व मादा के लिए क्रमशः 3.13 और 3.32 तक लम्बाई भार को संबध मिला तथा नर व मादा के लिए प्रौढ होने का आकार क्रमशः 87 मी.मी तथा 114 मी.मी. था । इस झींगे की जननक्षमता 0.58 से 4.5 लाख अण्डे देने की थी तथा एक मादा झींगा अपने जीवन काल मे पाँच बार अण्डे देने में सक्षम पाई गई । प्रौढ़ मादा का विकास अप्रैल और फिर अक्तुबर-नवम्बर में अधिक से अधिक होता है। अगस्त-सितम्बर माह में अधिकतम अण्डा उत्पादन का निरीक्षण किया गया । नर और मादा के लिए VBGF पैरामीटर L_{∞} क्रमशः 162 मी.मी. और 204 मी.मी. तथा वार्षिक आधारपर K 2.25 और 1.9 था । दोनों नर व मादा का संदोहन दर समक्रम में 0.72 तथा 0.58 था । प्रग्रहण की लंबाई नर और मादा में 113 मी.मी. तथा 115 मी.मी. थी । सहगण विश्लेषण (cohart analysis) व्दारा नर की जैविक मात्रा 170 टन तथा मादा की जैविक मात्रा 473 टन पायी गई । अध्ययन काल के दौरान नर व मादा का उत्पाद क्रमशः 443 टन तथा 1387 टन था । Y/R और B/R विश्लेषण यह दर्शाता है कि पैदावार वृध्दि के लिए मत्स्यन प्रयास में वृध्दि तथा प्रग्रहण लंबाई में कमी लाई जा सकती है परंतु थामसन और बेल मॉडल यह पूर्वानुमान देता है कि इससे आर्थिक घाटा होता है । मासिक सहगण के आधार पर स्टॉक रंगरुट संबंध के परीक्षण से रिकर मॉडल में अच्छा गुणांक सहसंबन्ध ("r" = 0.65) पाया गया । यह भी देखा गया कि यह संबंध युवा मादाओं की अपेक्षा प्रौढ मादाओं को प्रजनन स्टॉक की तरह लेने से बेहतर था । स्टॉक-रंगरुट संबंध से यह संकेत मिला कि 13 मिलियन अथवा 193 टन प्रजनन समूह से अधिक से अधिक परिवर्धन की संभावना है ।

ABSTRACT

Reproductive dynamics of *Metapenaeus affinis* (H. Milne Edwards) in Mumbai waters was investigated from December 1999 to November 2000. Samples of prawns, in addition to fishery data, were analysed from shallow nearshore (depth 5-10 m), nearshore (15-40 m) and offshore (upto 70 m) fishing areas. Exponent of length-weight relationship was 3.13 and 3.32 for male and female respectively. The size at maturity was 87 mm for males and 114 mm for females. Fecundity of the species ranged from 0.58 to 4.5 lakh eggs and an individual female prawn was found to spawn five times during its lifetime. The proportion of mature females was maximum in April and again in October-November, but the egg production was maximum in September. However, bulk of the recruitment was observed in August-September. The VBGF parameter L_∞ was 162 mm and 204 mm and K 2.25 and 1.9 on annual basis for the males and females respectively. Exploitation rate in the two sexes was 0.72 and 0.58 in the same order. The length at capture (L_c) was 113 mm and 115 mm for males and females respectively. Cohort analysis revealed a steady-state biomass 170 tonnes of males and 473 tonnes of females, while the total catch during the year of study was 443 tonnes for males and 1,387 tonnes for females. The relative Y/R and B/R analysis indicated that increase in fishing effort and reduction in length at capture would increase yield, but Thompson and Bell yield-stock prediction model showed that this would result in a loss in terms of economic returns. Stock recruitment relationship on monthly cohort basis showed presence of Ricker type of relationship, which was better when mature females instead of total adult females, were taken as the spawning stock. Maximum recruitment was possible with 13 million spawners or 193 tonnes of adult females as standing stock biomass.

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1. INTRODUCTION

Marine capture fisheries in the Indian Exclusive Economic Zone constitute a highly productive sector with an annual turnover of more than Rs 220 billion. It has emerged as the largest single industry in the country employing about 10 million people, generating 5.4 million tonnes of valuable animal protein and feed at least 500 million people every year, meeting the basic human needs such as nutrition, food security and sustainable livelihood (Sakthivel, 2001).

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India is a major contributor to the world production of marine crustaceans, which accounted for 17% of marine fish landings in the country in the year 2000. Out of this, 44% was penaeid prawns at 2.07 lakh tonnes (CMFRI, 2001). Frozen shrimps formed 71% of the total export earnings from the marine products in 1999 – 2000 (MPEDA, 2000). Total foreign exchange earned by shrimp export in 1999 – 2000 was Rs 3,648.96 Crores. The major importer countries of prawns were Japan followed by USA and the European Union.

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Increasing demand for the penaeid prawns in the international seafood market and the lucrative export value realised, has led most of the fishermen to go for high value crustacean resources. This has resulted in great technological advancement in fishing techniques by the improvisations of fishing vessels and gears as well as development of preservation, processing and storage methods (Devaraj and Vivekanandan, 1999). Penaeid prawns form the backbone of trawling industry in India. There has been a substantial increase in the number and efficiency of trawlers in the country in the past few decades. High value of penaeid prawns makes it a major resource for target fishing. Fish trawls have been modified as shrimp trawls by attaching sinkers to the net and by reducing codend mesh size. Trawlers are operated in the areas of high prawn abundance and night trawling is also undertaken to catch species that are nocturnal in habit.

The rapid growth in the trawling industry increased catch of penaeid prawns from 1.12 lakh tonnes in 1980 to 1.64 lakh tonnes in 1990 and peaked at 2.24 lakh tonnes in 1994. Subsequent to 1994, there has been a fluctuation in penaeid prawn landing with a low of 1.72 lakh tonnes in 1999 and a maximum of 2.14 lakh tonnes in 1998 (CMFRI, 1981, 1991, 1995, 1999, 2000).

Decline and fluctuations in catch after 1994 calls for an understanding of the resource characteristics and re-evaluation of stocks of various species of penaeid prawns in India. Devaraj and Vivekanandan (1999) gave warning signals about the health of a fishery. Decrease in abundance as reflected by decline in catch rate necessitates effective management of the available resources to maintain stock levels to get sustainable yield. Prerequisites for effective management of a stock are, understanding the biology of the species, assessment of the available stock and its response to changes in fishing level.

Two types of models used for analysing the dynamic nature of a stock are: surplus production or logistic model and analytical model. The first is simple and easily understood and makes only moderate demands for data. It takes into consideration only observable input of fishing effort and the actual output of yield in terms of catch per unit effort. Analytical or yield per recruit model deals with the age structure and various components that affect the stock like growth, mortality and size or age at capture and recruitment. The population is considered as a sum total of its individuals rather than as a single unit. Both these models assume the stock to be in steady state equilibrium, and recruitment is assumed to be constant from year to year. Recruitment is the main source of fish biomass for replacing the losses in the stock due to natural and fishing mortality. Decline in recruitment due to reduction in parental stock size is called recruitment overfishing.

Recruitment overfishing has been neglected for a long time in shrimp fisheries and the accepted paradigm was that because of high fecundity of shrimp and the importance of inshore nurseries in determining cohort survival, shrimp stocks were unlikely to be exploited intensely enough to cause recruitment problems and that economic factors probably would limit effort to below the level critical for shrimp stock reproduction (Garcia, 1989). Most of the evidence given in the past to demonstrate existence of stock-recruit relationships can be interpreted as artefacts owing to the short life span of shrimp and the autocorrelation in environmental variations (Garcia, 1983). Penn and Caputi (1985) presented some evidence that in a small and well-isolated stock off an arid zone, recruitment might be affected by fishing. It is of course obvious that at some high level of effort, problems of recruitment are to be encountered, although at levels of exploitation up to 70-80% no effort recruitment relationship was encountered in Northern Australia stocks (Staples *et al*, 1984). Scrutiny of the reproductive mechanism of shrimp populations showed that selective fishing of the main cohorts by the perfectly aimed shrimp trawl fishery could lead to severe disturbance of the delicate mechanism developed by shrimp through their evolution to cope with a highly seasonal environment (Garcia, 1989). It is therefore important to study the reproductive dynamics and stock-recruit relationship in penaeid prawns.

Recruitment, i.e., the number of young individuals entering a fishery should depend on the number of individuals producing that generation, or, in other words, the number of offspring should depend upon the number of spawning individuals. But in reality, recruitment does not always follow the trend in changes in stock size suggesting that recruitment depends not only on stock size but also on other factors. These factors could be reproductive success of a stock and an array of environmental parameters. In cases where recruitment is separated from the spawning event by a long period, the environmental conditions affect the survival of larvae or pre-recruit individuals (King, 1995). Therefore recruitment could depend upon the size of the spawning stock as well as on the prevalent environmental conditions.

Present endeavour is to study the reproductive dynamics of *Metapenaeus affinis* and to examine the stock-recruit relationship, if any, shown by the species in Mumbai waters.

Metapenaeus affinis (H. Milne Edwards) is the third most important penaeid prawn in Maharashtra after *Parapenaeopsis stylifera* and *Solenocera crassicornis* constituting about 11% of total penaeid prawn in the state (CMFRI, 2001). In terms of value, it is priced at Rs 100 – 180 depending on size as compared to Rs 30 – 40 of the former. It is highly valued in domestic and foreign markets and exported as 'medium brown'.

In order to describe the reproductive dynamics of the species, various biological parameters such as growth, mortality and population fecundity have been investigated. Similarly, the population parameters such as growth and mortality have been estimated to know the dynamics of the stock, which may help in predicting the effect of changes in fishing effort on future yields in terms of weight as well as value. In addition to the data analysed in the present investigation, the data available from the grey literature were used to identify the periods of intensive spawning, peak recruitment and periods when maximum harvesting was advantageous. The relationship between adult stock and/or spawning stock and the recruits of the species would help to apportion the adult stock of the species that would need conservation measures for maximising the recruitment of juveniles and sub-adult prawns in the fishery. These investigations may help in identifying management strategies such as closed fishing during intense spawning or regulating the catch of the adult prawns during spawning months.

2. REVIEW OF LITERATURE

Prawn fishery of India has been reviewed extensively by Panikkar and Menon (1956), Jones (1969), Mohamed (1967, 1973), Kurien and Sebastian (1976), Silas *et al.* (1984), Rao (1986), Suseelan and Pillai (1993). Among them, Silas *et al.* (1984) gave a detailed review of the shrimp fishery in India from 1962 to 1981 and suggested management measures that could be adopted to ensure maximum sustainable yield of shrimps in Indian waters. Suseelan and Pillai (1993) reviewed the stock assessment of crustacean fishery resources of the country based on the landings during 1984 – 1992. Prawn landings during that period accounted for 72% of crustacean fishery and had showed a 'remarkable leap' due to extended fishing by shrimp trawlers over time and space.

Ramamurthy (1994) gave the penaeid prawn trawl fishery of the northwest coast of India, in an area extending from Ratnagiri in the south to Surat in the north in depths of 20 – 60 m where *M. affinis* was found to occupy second or third place in abundance during the different years. Maheshwarudu *et al* (1996) studied the catch and effort data of penaeid prawns from 1986 – 1993 in Palk Bay and reported the change in the abundance of *M. affinis* in the area. Patkar (2001) gave the changes in penaeid prawn landings from 1961 to 2000 in India and in Maharashtra.

Deshmukh *et al.* (2001) reported that *M. affinis* was the third most dominant species after *Parapenaeopsis stylifera* and *Solenocera crassicornis* in the nearshore waters off Mumbai.

Fishery of *M. affinis* outside India has been described by Vibhasiri (1988) in the Gulf of Thailand, where it is the most dominant species among the penaeid prawns and by Mathews (1989) in Kuwait where it forms a major species, second only to *Penaeus semisulcatus* in abundance. Distribution of *M. affinis* was given by Holthuis and Miquel (1984).

2.1 Dimensional Relationships:

Dimensional relationships such as relationship between total length and total weight; total length and carapace length etc. in penaeid prawns have been reported by a number of researchers. George (1959) gave the length-weight relationship in juveniles of *Metapenaeus monoceros* from Cochin backwaters. Length-weight and total length-carapace length relationships in *M. brevicornis* in Hooghly-Matlah estuary were given by Rajyalakshmi (1961, 1981). Rao (1967) gave the length-weight relationships in male and female *Penaeus indicus* and *P. monodon* from Chilka Lake. The same in *P. semisulcatus* was given by Thomas (1975). From the Kakinada coast, dimensional relationships for *P. monodon*, *Metapenaeus monoceros* and *M. dobsoni* was given by Lalitha Devi (1987) and in *M. monoceros* by Rao (1988). Sukumaran *et al.* (1993a) reported the length-weight relationship of *Metapenaeus dobsoni* from different fishing grounds of India. Length-weight and total length-carapace length relationships of male and female *Metapenaeopsis barbata* were given by Ramaseshaiah and Murthy (1997) and Primavera *et al.* (1998) gave the morphometric relationships in *Penaeus monodon* and studied the difference in these relationships according to life stage, sex and source. Nandakumar (1998) gave the length-weight relationship and other dimensional relationships for *M. monoceros* from Cochin waters. Patkar (2001) and Karnik (2002) gave various dimensional relationships in *Metapenaeus brevicornis* and *M. monoceros* respectively, from Mumbai waters.

Dimensional relationships in case of *M. affinis* from Mumbai were given by Mehendale (1959). Subrahmanyam (1963) gave the length-weight relationship combined for the two sexes and Ramamurthy and Manickaraja (1978) gave the relation between tail and total lengths and total and carapace lengths for three commercial species of penaeid prawns including *M. affinis* and Achutankutty and Parulekar (1986) gave the length-weight relationship of *M. affinis* along with other species in Goa waters. Morphometric relationships in *M affinis* from the Arabian Gulf were given by Farmer (1986).

2.2 Dimorphic Characters:

The reproductive system and the microscopic structures of the reproductive organs of the important penaeid prawns were studied by Hudinaga (1942), King (1948), Shaikhmahmud and Tembe (1960), Tuma (1967), Castille and Lawrence (1991) and Damle (1991). Structure of reproductive system of *Metapenaeus affinis* was studied by Rao (1968) and microscopic study of the gonads of the prawn was done by Mehendale (1959) and Rao (1968). George and Rao (1968) described the structure and development of external genitalia in some Indian prawns including *M. affinis*.

2.3 Length-at-Maturity:

A few studies have been undertaken to determine the size at first maturity in *Metapenaeus affinis*. Mehendale (1959) gave a size range in male and female *M. affinis* at which they were observed to attain sexual maturity. Subrahmanyam (1963) gave the smallest size at which the prawn was found to be mature in the Malabar Coast. Similarly, Rao (1968) regressed the percentage of mature females and found the minimum size at maturity of the species along the southwest coast of India. Ramamurthy *et al.* (1975) determined the minimum size of maturity of the prawn along the Mangalore coast. Minimum size at maturity and the size at 50% maturity of *M. affinis* in Kuwait waters have been reported by Mathews (1989).

2.4 Monthwise Maturity Distribution:

Many workers have used distribution of mature females in different months to determine the spawning season of a species. Early works on *M. affinis* were done by Mehendale (1959), George (1961), Subrahmanyam (1963), Mohamed (1967) and Rao (1968). Ramamurthy *et al.* (1975) reported the spawning season of the species along the Mangalore coast. The same has also been studied in other species of penaeid prawns *M. brevicornis* (Rajyalakshmi, 1981); *M. monoceros* (Nalini, 1976, Rao, 1989, Nandakumar, 2001). Mathews (1989) described the spawning habit of the species in Kuwait. Goswami *et al.* (1977) and Achunthankutty and Nair (1983) studied the larval abundance of the prawn to determine the spawning season.

2.5 Spawning Periodicity:

Initial work on the spawning periodicity in fishes by examining the eggs was done by Hickling and Rutenberg (1936) and De Jong (1940). Prabhu (1956) used the size frequencies of ova in ovaries to determine the spawning periodicities in some fishes.

Various workers have used size frequency of ova to determine spawning periodicity in penaeid prawns. Shaikhmahmud and Tembe (1960) used the method in *Parapenaeopsis stylifera*, Thomas (1974) in *Penaeus* *semisulcatus*, Nalini (1976) in *Metapenaeus monoceros*, and Rao (1989) in *M. monoceros*. Rao (1968) studied the ova diameter in *M. affinis* in addition to other penaeid prawns but Mehendale (1959) opined that ova diameter frequency couldn't be used in case of *M. affinis* due to large overlapping of egg size in different stages of maturity.

Thomas *et al.* (1974) studied the spawning of *M. affinis* by experiments conducted in the laboratory.

2.6 Sex Ratio:

Early reports of male to female sex ratio in *M. affinis* were by Menon (1957), Mehendale (1959), Shaikhmahmud and Tembe (1960) and George and Rao (1967). Subrahmanyam (1963) reported the sex ratio in the prawn in coastal waters off Calicut, George *et al.*(1963) from the offshore waters off Cochin and Ramamurthy *et al.* (1975) along the Mangalore coast. Vibhasiri (1988) gave the sex ratio in *M. affinis* in the Gulf of Thailand and Mathews (1989) gave the same in the stock in Kuwait.

Among the recent works on related species in Mumbai waters, Patkar (2001) and Karnik (2002) reported the sex ratios in *Metapenaeus brevicornis* and *M. monoceros* respectively.

2.7 Fecundity:

Work on the fecundity of Indian prawns has been done on many different species. Rao (1968) gave the fecundities and relationships between total length and fecundity of *Metapenaeus dobsoni*, *M. affinis*, *Penaeus indicus* and *Parapenaeopsis stylifera*. Fecundity of *Penaeus semisulcatus* has been given by Thomas (1974). Nalini (1976) studied the fecundity of *Metapenaeus monoceros*. Sukumaran and Rajan (1981) studied the fishery and biology of *Parapenaeopsis hardwickii* from Bombay area and have given the fecundity and the relationship between fecundity and total length of the prawn. Rao (1989) in his work on the reproductive biology of *Metapenaeus monoceros* gave the fecundity and its relationships with total length, total weight and ovary weight.

Extensive work has been exported from the Australian waters on reproductive dynamics of penaeid prawns. Tuma (1967) worked on *Penaeus merguiensis*; Penn (1980) on *P. latisulcatus*, Crocos and Kerr (1983) described the maturation and spawning of *P. merguiensis*, Crocos (1987a) studied the reproductive dynamics of *P. semisulcatus*.

Velázquez and Garcia (2000) have studied and compared the fecundities of *Litopenaeus setiferus*, *Farfantipenaeus aztecus* and *F. duorarum* in the Gulf of Mexico.

2.8 Population Fecundity Index:

Population fecundity index has been used as a measure of the magnitude of spawning in penaeid prawns by some researchers in Australia. Penn (1980) used population fecundity index in combination with spawning frequency to find out the spawning season in *Penaeus latisulcatus*. Crocos and Kerr (1983) determined the population fecundity index for *P. merguiensis*, Crocos (1987a) for *P. semisulcatus* and Crocos (1987b) for *P. esculentus*. Population fecundity indices have also been determined for *P. longistylus* and *P. latisulcatus* (Courtney and Dredge, 1988). Crocos and Velde (1995) used population fecundity based on the abundance and fecundity of spawners to describe the spawning patterns of *P. semisulcatus* in the Gulf of Carpentaria.

2.9 Age And Growth:

Age and growth of *Metapenaeus affinis* has been described by some researchers in India and abroad. Mohamed (1967) described the monthly growth in the prawn caught from 12 – 22 fathom depth off Mumbai and Pauly *et al.* (1984) estimated the growth parameters using the same data. Subrahmanyam (1963) described the monthly growth along the Malabar Coast, giving differential growth in males and females of the species. Ramamurthy *et al.* (1975) estimated the VBGF parameters in male and female *M. affinis* along the Mangalore coast. Achuthankutty and Parulekar (1986) described the growth of the prawn in Goa waters. Vibhasiri (1988) described the same in Ban Don Bay, in the Gulf of Thailand, and Mathews (1989) in Kuwait. Paralkar (1990) studied the species in Mumbai waters.

Pauly *et al.* (1984) studied the growth pattern and growth performance indices of various penaeid prawns including *M. affinis.* Longhurst and Pauly (1987) studied and reviewed the growth patterns and growth performance index in penaeid prawns. Rao and Krishnamoorthy (1990) reported the growth pattern of the related species *M. monoceros.*

2.10 Mortality:

Natural, total and fishing mortalities in *M. affinis* from different areas have previously been reported by a few workers (Ramamurthy *et al*, 1975; Pauly *et al*, 1984; Vibhasiri, 1988; Mathews, 1989 and Paralkar, 1990). Garcia and Le Reste, 1981 and Pauly *et al*, 1984 discussed and reviewed the work done on mortality estimates of penaeid prawns in tropical waters.

2.11 Stock Assessment:

Stock assessment of *M. affinis* in Indian waters has not yet been reported even though it forms a very important species along the Northwest coast of India. But stocks of the species have been assessed in the Gulf of Thailand (Vibhasiri, 1988) and Kuwait (Mathews, 1989 and Mohammed, 1995).

Stock assessments of some other species of penaeid prawns in Indian waters have been reported. Rao *et al.* (1993) assessed the stocks of *Penaeus* sp. off the east coast of India. Two metapenaeid prawns, *M. monoceros* and *M. dobsoni*, have been particularly extensively studied (Sukumaran *et al.*, 1993b, Rao, 1994, Ramamurthy *et al.*, 1978, Paralkar and Devaraj, 1990 and Sukumaran *et al.*, 1993a).

2.12 Stock Recruitment Relationship:

The work on stock recruitment relationship in fishes was started by Ricker (1954). The classical models of stock recruitment curve were given by Ricker (1954, 1975), Beverton and Holt (1957) and Shepherd (1982). Study of stock recruitment in penaeid prawn started only in early 1980s. Garcia and Le Reste (1981) and Garcia (1983) reviewed the work done on stock recruitment relationship in prawns. Brunenmeister (1984) analysed the relationships in *Penaeus setiferus* and *P. aztecus* in the Gulf of Mexico. Rothschild and Parrack (1981) also found a stock recruitment relationship in the Gulf of Mexico for *P. aztecus* and *P. setiferus* by different measures of stock and recruitment sizes, the results of which were confirmed by Nichols (1981).

Parrack (1981) proposed stock recruitment relationships in *P. aztecus* in the Gulf of Mexico on monthly cohort basis. Boddeke (1982) also analysed the stock recruitment relationship on a monthly basis by using stock size in a month and recruitment four months later. Morgan and Garcia (1982) analysed the relationship in *P. semisulcatus* in Kuwait waters.

Staples (1985) discussed the recruitment processes of *P. merguiensis* in the Gulf of Carpentaria, Australia, and Penn and Caputi (1986) have discussed the relationship between spawning stock, recruitment and environment in *P. esculentus* in Exmouth Gulf, Western Australia. Longhurst and Pauly (1987) reviewed and discussed the work done on stock recruitment relationship in penaeid shrimp.

No work has yet been reported on the stock recruitment relationship in penaeid prawns in India. The present attempt is to study such relationship.

3. MATERIALS AND METHODS

For investigations on the reproductive dynamics of *M. affinis*, the species was studied for a period of one year (Dec. 1999 – Nov. 2000) from two landing centres in Mumbai, *viz.* New Ferry Wharf and Versova. At New Ferry Wharf the shrimp trawlers fish in offshore waters at a depth of 20 – 70 m in a fishing area extending from south of Saurashtra coast to Ratnagiri. At Versova the trawlers fish at a depth of 15 - 40 m, parallel to the coastline, from Vasai in the north and Murud-Janjeera in the south. This has been referred to as nearshore waters in the present study. Hand trawlers operate in shallow nearshore waters at a depth of 5 –10 m and undertake daily fishing. So the samples collected from three different types of trawlers represented the entire coastal ecosystem, including the very shallow inshore waters.

Catch, effort and length-frequency data were collected from all the three landings on a weekly basis. Samples of the species were collected monthly from each depth zone and analysed in the laboratory fresh condition or sometimes after preservation in 5% formalin. The price of the species in different size categories was noted from the auctions carried out at the landing centres.

In order to study the stock recruitment relationship in the species, catch and effort data collected by the Mumbai Research Centre of CMFRI for the period Dec. 1997 to Nov. 2001 were used.

3.1 Size Composition:

To study the catch and landing patterns of *M. affinis*, weekly measurements were taken from trawl landings at New Ferry Wharf and Versova and hand trawl landings at Versova for a period of one year – from December 1999 to November 2000. There was no landing in the months of June and July at Versova due to closure of fishing during monsoon.

A total of about 100 specimens were measured for length – frequency studies every week from each landing centre. Each specimen was measured for total length from tip of rostrum to the end of telson to the nearest millimetre. Sex and stage of maturity (in case of females) was noted down. Total weight of the sample was taken using a single pan Yamato balance.

The length measurements were grouped into 5 mm size class intervals and the number of individuals in a size class noted down separately for males and females. The length frequency so obtained was raised to the total catch of the species for the day of sampling. The raised frequency for each sampling day was again raised to the monthly estimated total catch of the species. Month wise length frequency obtained in this way was used for the various methods employed to describe the stock of *M.affinis* in Mumbai waters.

3.2 Dimensional Relationships:

Monthly samples were collected from offshore, nearshore and shallow nearshore waters. Each sample contained about 50 specimens. The samples were kept frozen at –20^{0}C until they were analysed in the laboratory. On the day of analysis, the sample was thawed under running tap water. Following measurements were then taken:

a) Total length was measured from tip of rostrum to the tip of telson to the nearest millimetre.

b) Carapace length was measured as length from dorsal portion of the postorbital margin to mid posterodorsal margin of the carapace.

c) Total weight as total wet weight of the specimen was noted after lightly drying the prawn on cloth or tissue paper.

d) Tail weight of the specimen was taken after removing its head (cephalothorax).

e) Meat weight was noted down as the weight of the abdomen after removing the exoskeleton.

Dimensional measurements of 431 males in the size range of 66 – 152 mm and 654 females in the size range of 69 –175 mm were taken to arrive at various relationships for the males and females separately. The relationships were obtained by linear regression based on the method of least squares. Different relationships worked out were total length and total weight, total length and carapace length, carapace length and total weight, total weight and tail weight and total weight and meat weight.

The length-weight relationship is exponential and given by (Le Cren, 1951):

$$W = a L^b$$

where 'a' is a constant while 'b' is an exponent. The equation is transformed into linear form by taking natural logarithms on both sides

$$Ln\ W = Ln\ a + b\ Ln\ L$$

Total length-carapace length relationship is linear and it was determined as

$$Y = a + bX$$

where 'a' is a 'Y' intercept while 'b' is the slope.

3.3 Dimorphic Characters:

Sex of the specimen was noted down based on the presence of external genitalia such as thelycum in case of females and petasma in case of males. Males were determined as immature or mature based on the absence or presence of spermatophores. Males with joint petasmal endopodites and clearly visible spermatophores in the terminal ampoules situated at the base of the fifth pereopod, were considered as mature. Gonadal phase of the females was determined macroscopically according to the colour and size of the ovary seen through the abdominal exoskeleton and microscopically by studying the stage of the ova under a compound microscope. Ovary was distinguished into five stages of maturity as given by Rao (1968).

Histology:

In order to microscopically examine the structure and development of ovaries, sections of different stages of maturity were fixed and stained by the following methods –

a. Fixation – Ovaries were dissected out and a 2-3 mm sized piece of tissue was kept in Bouin's fixative for 2-3 hours.

b. Dehydration – Tissue was passed through grades of ethyl alcohol to dehydrate the tissue completely. The grades used were 30%, 50%, 70%, 90% and absolute alcohol.

c. Clearing – Tissues were cleared of alcohol by leaving them in xylene for about 2 minutes.

d. Infiltration – Dehydrated and cleared tissues were impregnated with paraffin wax. After two changes in the molten paraffin wax, blocks were made with tissue in the middle to facilitate sectioning.

e. Section cutting – 6-8 μm thick sections of tissue embedded in wax were cut using rotary microtome. These were then fixed on warm slides using Mayer's albumin (glycerine and egg white 1:1).

f. Staining – Hematoxylin and eosin were used as stains. Sections fixed on slides were first cleared in xylene and then passed through descending grades of alcohol for rehydration. Rehydrated sections were then stained with hematoxylin and dehydrated again before staining with eosin. Sections were then dehydrated completely in absolute alcohol and then cleared in xylene.

g. Mounting – Sections were mounted using DPX mountant. After removal from xylene, the stained sections were covered with DPX mountant and a cover slip was gently placed over it and pressed down to remove any air bubbles.

3.4 Length- at- Maturity (L_m):

For the estimation of length at which 50% of the individuals in a size class attain sexual maturity, the method given by King (1995) was used. In this method, the proportion of ripe individuals (III and IV stage of maturity in case of females and individuals with united petasma and clearly visible spermatophores in case of males) was noted for each size class, separately for males and females. Often it was seen that even in larger length classes of females, the proportion of ripe individuals in a size class was less than 1, i.e., not all mature individuals were in a ripe condition at any given time. So the proportion of ripe females was adjusted in accordance with the maximum proportion of the ripe individuals in any size class in the sample. This adjusted proportion was expressed as "p" in the following equation

$$p = 1/\{1 + \exp[-b\,(L - L_m)]\}$$

L_m (length at maturity) in the equation was calculated by the linear regression of length L against Ln [(1-p)/p] and the parameter 'b' was estimated.

The expected proportion "P" for each size class was calculated as

$$P = 1/\{1 + \exp[-b\,(L - L_m)]\}$$

The graph of proportion P was plotted against length L to find the size at which 50% of the individuals are in mature condition.

3.5 Monthwise Maturity Distribution:

Maturity stages in the case of males could not be distinguished. Monthwise maturity distribution in case of females was established on the basis of the percentage of females in different stages of maturity every month for the three fishing areas. Percentage of mature and ripe females (Stage III and IV) was calculated to find out the months of maximum spawning.

3.6 Spawning Periodicity:

In order to determine the spawning periodicity of the prawn, size distribution of the ova in mature ovaries was studied. Ovaries were hardened in 5% formalin for 2 – 5 days and then dissected out. The ova were observed under microscope and the diameters of about 200 ova were measured in micrometer division (1 m.d. = 0.02 mm) using ocular micrometer. About 200 ova were measured. Immature ova with diameter less than 0.08 mm, which formed the ground stock, were ignored.

3.7 Sex Ratio:

Sex ratio in the three fishing areas, as well as the sex ratio for the entire population, was estimated from the weekly length frequency data collected at the landing centres. The length frequency data was noted down as number of males and females collected in each month to estimate monthwise sex ratio and separated into size classes to estimate the sizewise sex ratio. Total numbers were pooled together to estimate the sex ratio of *M.affinis* in the three fishing areas. The sex ratios were tested by χ^2 method at 5% significance level.

3.8 Fecundity:

For fecundity estimation, fully mature (ripe) females in the IV stage of ovary development were collected from the three fishing areas. No differentiation was made between the areas for fecundity studies. The collected females were in the size range of 102-162 mm in total length. These specimens were collected fresh from the landing centres and preserved in 5% formalin for a minimum of five days. Fecundity was estimated for 67 such females.

At the time of fecundity measurement, a specimen was first washed in clean tap water and total length and total weight were noted down. After this, the complete ovary was dissected out, extraneous bits of tissue removed, and it was carefully weighed to the nearest milligramme. A fraction of the ovary from the lateral lobe, weighing around 0.01g, was removed and carefully weighed. Distribution of ova in the anterior, middle and posterior regions did not show any marked variation; so, for all further studies a fraction was taken from the right lateral lobe to maintain uniformity.

Total number of ripe ova in the weighed fraction was counted under a stereoscopic binocular dissecting microscope and then the total number of ova in the entire ovary was calculated as:

$$F = \text{Ovary weight} * \text{No. of ova in the fraction/ wt. of fraction}$$

Least square regression analysis was employed to calculate the relationship of fecundity to total length, total weight and ovary weight.

3.9 Population Fecundity Index:

Population fecundity index for each month for the three fishing areas for the period of Dec. 1999 to Nov. 2000 was calculated by the method given by Courtney and Dredge (1988). The formula is given as:

$$PFI = n^* \sum S_{CL} * P_{CL} * F_{CL}$$

Where, n is the total number of adult females in the month

S_{CL} is the proportion of adult females in a size class

P_{CL} is the proportion of mature females in adult females in a particular size class and

F_{CL} is the fecundity in a size class.

Total number of females raised to the monthly catch and the numbers of adult and mature females raised in similar way in a size class for each month were used to calculate the monthly population fecundity index.

3.10 Age And Growth:

Using the length frequency data raised to monthly catch as input, the following methods were employed to study the age and growth of *M.affinis* by using FiSAT (FAO-ICLARM Stock Assessment Tools) computer programme (Gayanilo *et al*, 1996). Growth parameters asymptotic length (L_∞) and growth coefficient (K) of von Bertalanffy Growth Function (VBGF) were estimated using various methods.

3.10.1 Modal Progression Analysis (Banerji and George, 1967):

In this method, modal size was determined and the progression of modes traced, separately for males and females. Modal class from the length frequency data was identified and modal size was determined by the formula:

$$L_m = L_1 + \frac{(f_m - f_1)h}{(2f_m - f_1 - f_2)}$$

Where L_m – modal size, L_1 – lower class limit of the size group, f_m – modal frequency, f_1 – frequency prior to the modal frequency, f_2 – frequency next to the modal frequency, h – class width.

Month wise modal sizes were plotted on a graph sheet and their progression was followed by eye fitted curve. The rate of change of length per month ($\Delta L/\Delta t$) was used to estimate L_∞ and K by Gulland and Holt plot (Gulland and Holt, 1959), where $\Delta L/\Delta t$ was plotted against mean length (L). From the regression analysis intercept 'a' and slope 'b' were obtained and employed for the estimation of L_∞ and K as follows:

$$L_\infty = -a/b$$

$$K = -b$$

3.10.2 ELEFAN I Method (Pauly and David, 1981):

Length frequency data was analysed using ELEFAN I package given by Pauly and David (1981). Initial estimate of L_∞ was taken by dividing the maximum observed length (L_{max}) by 0.95 as suggested by Pauly (1980b). Lengths close to the initial L_∞ were tried and the estimates with the maximum Rn values (index of goodness of fit) were arrived at. Different methods available in ELEFAN I package, such as "automatic search routine" and "response surface analysis", were tried to arrive at the values of L_∞ and K. Various values of L_∞ and K were tried by iteration by using variable Starting Samples (SS) and Starting Lengths (SL) and the best fitting growth lines with the maximum Rn values were selected.

3.10.3 Powell-Wetherall Method (Wetherall *et al*, 1987):

Using this method, L_∞ and Z/K were estimated. L' in the Powell-Wetherall plot was selected which can take any value equal to and above the smallest length under full exploitation. Estimates of L_∞ and Z/K were arrived at by selecting the value of L' giving the best value of regression coefficient "r".

3.10.4 von Bertalanffy plot (von Bertalanffy, 1934):

Using this method in the FiSAT package (Gayanilo *et al.*, 1996) the estimates of L_∞, K and t_0, along with their standard errors and coefficient of variation were obtained following seasonalised as well as non-seasonalised growth.

3.10.5 Bhattacharya method:

The multimodal length frequency obtained for the two sexes was subjected to computer based Bhattacharya analysis (Sparre *et al.*, 1989) in which the size frequency was resolved into normal distributions to obtain their mean lengths and standard deviations. These mean lengths and their standard deviations were used for the following methods to estimate growth parameters.

3.10.5a Gulland and Holt plot (1959):

A growth increment file created by linking of mean sizes obtained from Bhattacharya analysis, was used in the FiSAT programme and estimates of L_∞ and K were obtained.

3.10.5b Faben's method (1965):

L_∞ and K along with their standard errors are estimated by predicting length at recapture based on the current parameter selection and the length at marking. The growth parameters are estimated by minimising the Sum of Square of Errors (SSE), *i.e.*, the squared differences between the observed lengths at second reading (Lr) and the predicted length (Lr').

3.10.5c **Appeldoorn's method** (1987):

This method, based on Appeldoorn (1987) and Soriano and Pauly (1989), allows the use of growth increment data to estimate the parameters of a seasonally oscillating version of the VBGF. The minimum and maximum constraints, as well as the starting values for the growth parameters L_∞, K, C and WP are used as inputs.

3.10.6 Growth Performance Index (Pauly, 1980c):

Growth performance index gives the growth performance of a species based on two growth parameters K and L_∞ (or W_∞) and links growth performance and oxygen supply. Growth performance indices can be used to compare growth in different species within groups such as genera or families. Growth performance index was calculated as:

$$\varphi = \log_{10}K + 2/3 \log_{10}W_\infty$$

$$\varphi' = \log_{10}K + 2 \log_{10}L_\infty$$

3.11 Mortality

Total Mortality

Following methods were used to estimate total mortality:

3.11.1 Length-Converted Catch Curve:

Linearised catch curve or length-converted catch curve is a graphical representation of the logarithms of numbers caught plotted against age. This gives an inverted 'V' shaped curve, the ascending part of which represents the number of fish that are partly vulnerable to the gear.

The descending part represents the decline in the surviving population. The linearised slope of the descending part, with sign changed, represents the total mortality coefficient.

In case of prawns, where the growth in length is not linear, Pauly *et al.* (1984) gave a slightly modified method in which the lengths of prawns are converted into age by inverse VBGF and the numbers caught in each length group is divided by the time needed to grow through a length class. Thus, the length-converted catch curve equation is given as

$$\text{Ln}\ (N/\Delta t) = a + bt$$

where N is the number of prawns in the length class
Δt is the time required for the prawn to grow through a length class
t is the age corresponding to mid length
b (with sign changed) is the coefficient of total mortality Z.

Natural Mortality

Following methods were used to estimate the natural mortality of the species:

3.11.2 Alagaraja's (1984) Model:

The following equation was used to estimate natural mortality corresponding to 1% survival:

$$M1\% = -\ln (0.01)\ T_m$$

Where, M1% stands for natural mortality corresponding to 1% survival and T_m for the longevity.

3.11.3 **Pauly's empirical equation** (Pauly, 1980a and Pauly *et al.* 1984):

The following empirical formula given by Pauly (1980a) and Pauly *et al.* (1984) was used to calculate natural mortality M:

$$\text{Log } M = -0.0066 - 0.279 \text{ Log}_{10}L_\infty + 0.6543 \text{ Log}_{10}K + 0.4634 \text{ Log}_{10}T$$

Where L_∞ and K are the von Bertalanffy growth parameters and T is the average annual temperature at the surface in degree centigrade.

3.11.4 Rikhter And Efanov's formula (1976):

Rikhter and Efanov's model relates natural mortality to the age at which 50% of the stock reaches the age of "massive spawning" (t_{mass}). The equation used was:

$$M = \frac{1.512}{(T_{m50\%} 0.72)} - 0.155$$

T_{mass} was calculated as the age corresponding to the length at maturity (L_m) by converting length into age by the inverse von Bertalanffy equation.

3.12 Probability Of Capture:

Probability of capture of male and female *M.affinis* by trawl net was estimated and selection curve plotted using FiSAT routine. Selection parameters L_{25}, L_{50} and L_{75} were estimated using moving average, L_{25}, L_{50} and L_{75} being the lengths at which respectively 25%, 50% and 75% of the prawns are retained in the cod end.

3.13 Length Based Cohort Analysis:

For observations on the numbers caught in each age/length group, the cohort analysis was used to estimate how many fish there must have been in the sea to account for that catch.

Length structured virtual population analysis or cohort analysis is used when the resource is moderately or heavily exploited. It was developed by Fry (1949) and revised by Pope (1972) and Jones (1984). The principle of this method is that if the number of fish of a given cohort alive at the end of a year and the numbers caught during that year is known, and if allowance is made, then the numbers at the beginning of the year can be estimated. The same process can be repeated for the previous year and so on, when the cohort entered the fishery. Thus, reconstruction of the entire population is made.

Natural mortality estimated by Pauly's method was used as input. Fishing mortality estimated by catch curve method was used as the terminal fishing mortality (F_t).

Thus, population sizes and fishing mortality for all length groups were computed. An F-array representing the fishing mortality for each length group, the reconstructed population (in numbers) and the mean stock biomass by length class were thus obtained.

3.14 Relative Y/R And B/R Analysis

To predict the effect of fishing effort and mesh size on *M.affinis* stock, modified version (Pauly and Soriano, 1986) of Beverton and Holt's (1957) "Yield per recruit" model was used. This model requires Lc/L_∞ and

M/K ratios as inputs. The Lc values obtained from the 'selection ogive' was used for computing the Y'/R values.

In this programme 'E_{max}' gives the exploitation ratio at which the maximum yields can be obtained. Similarly, $E_{0.1}$ gives the exploitation ratio at which the marginal increase of relative yield per recruit is 1/10th of its value at E=0 and $E_{0.5}$ gives the exploitation under which the stock is reduced to 50% of its unexploited biomass.

It is important to include B'/R (biomass-per-recruit) curve along with the Y'/R curve because Y'/R curve generally does not have a maximum and can give wrong impression that effort can be increased indefinitely. B'/R gives an idea of the change in biomass in response to change in effort, so that the two graphs together give a better picture of the stock. Biomass-per-recruit is given as (Sparre and Venema, 1992):

$$B'/R = (Y'/R)/F$$

3.15 Thompson And Bell Yield-Stock Prediction:

Thompson and Bell yield-stock prediction model (Thompson and Bell, 1934) was used to predict the yield in terms of weight and value based on the data on age specific fishing mortality and gear selectivity. The FiSAT package (Gayanilo *et al*, 1996) was used to predict the catch of male and female *M. affinis* exploited by trawl nets. The method consists of two parts:

- An analysis based on fishing mortalities per size group (the F-array), size specific catches, death, yields, biomasses and values. Output of the length structured VPA was used as input.
- A prediction of the effect of changes in the F-array on the catches, deaths, yields, biomasses and values.

Output was obtained in the form of yield, value and biomass estimates for a range of 'f' factors (proportion of F corresponding to the fishing condition) for males and females and the cumulative yields.

3.16 Stock Recruitment Relationship:

Catch and effort data collected by Mumbai Research Centre of CMFRI from the period Dec. 1997 to Nov. 2001 was used to examine the stock recruitment relationship in *M. affinis*. Monthly cohort analysis was carried out to get the monthly sizewise catch in numbers and weight. These were then grouped into: spawning stock comprised of size groups larger than length-at-maturity (L_m) and the recruits comprising of sizes smaller than L_m.

The spawning stock and the recruits were identified by using method given by Parrack (1981). In this method, monthly length based cohort analysis was carried out to estimate the biomass and numbers present in the sea in each month. Prawns above the length at maturity (L_m) and older were used as a measure of spawning stock and this was correlated with the number of juveniles available three months later.

3.16.1 Beverton and Holt (1957):

Beverton and Holt equation, which gives a recruitment curve hyperbolic in shape, is given as –

$$R = 1/(\alpha + \beta/S)$$

Where R is recruitment, S stock and α and β are parameters of the equation.

Linear regression was carried out as S/R against S in the equation (Paulik, 1973):

$$S/R = \beta + \alpha S$$

3.16.2 Ricker (1954, 1975):

The Ricker model describes a dome shaped curve and is given by the equation –

$$R = S \exp a (1-bS)$$

Linear form of the regression was carried out as Ln (R/S) against S in the equation

$$Ln (R/S) = a - (b) S.$$

4. RESULTS

Monthwise catch, CPUE (catch per hour of trawling) and percentage of *M. affinis* in total penaeid prawn landed at New Ferry Wharf and Versova during Dec. 99 – Nov. 2000 is given in Tables 1 and 2. It is seen that 1614.67 tonnes of the species was landed at the catch rate of 1.05 kg/hr. The species contributed 11.74% to the total penaeid prawns. Similarly, at Versova a total of 517.9 tonnes of *M. affinis* was landed at the catch rate of 1.45 kg/hr and it constituted 12.08% of the total penaeid prawns.

Plate 1 shows the male and female of *M. affinis* and Plate 2 shows a catch of the prawn at Versova landing centre.

It is seen that the CPUE of *M. affinis* was maximum in the month of August at New Ferry Wharf (3.32 kg/hr) as well as Versova (4.59 kg/hr). Similarly, at both the centres trawlers recorded minimum CPUE (0.27 kg/hr and 0.48 kg/hr) in the month of April.

Table 1: Catch, C.P.U.E and percentage of *M. affinis* in total penaeid prawns from trawlers at New Ferry Wharf

MONTH	CATCH (in Kg)	C.P.U.E (Kg/hr)	TOTAL PENAEID PRAWN (in Kg)	%
Dec. 1999	306, 010	1.42	2021, 656	15.14
Jan. 2000	120, 035	0.71	1693, 059	7.08
Feb. 2000	63, 107	0.4	979, 187	6.44
Mar. 2000	88, 059	0.51	1561, 101	5.64
Apr. 2000	55, 290	0.27	1109, 293	4.98
May 2000	45, 886	0.45	543, 883	8.43
Jun. 2000	37, 371	1.38	240, 693	15.53
Jul. 2000	29, 513	1.29	272, 120	10.84
Aug. 2000	94, 987	3.32	595, 090	15.96
Sep. 2000	420, 976	3.05	1861, 777	22.61
Oct. 2000	269, 235	1.69	2102, 084	12.81
Nov. 2000	84, 202	0.57	778, 228	10.82
TOTAL	**1614, 671**	**1.05**	**13,758,171**	**11.74**

Table 2: Catch, C.P.U.E and percentage of *M. affinis* in total penaeid prawns at Versova

MONTH	CATCH (in kg)	C.P.U.E (Kg/hr)	TOTAL PENAEID PRAWN (in Kg)	%
Dec. 1999	47, 813	1.36	463, 622	10.31
Jan. 2000	18, 247	0.49	570, 803	3.2
Feb. 2000	16, 000	0.58	264, 219	6.05
Mar. 2000	18, 556	0.62	315, 387	5.88
Apr. 2000	20, 706	0.48	359, 386	5.76
May 2000	27, 966	0.64	414, 116	6.75
Jun. 2000	16, 961	1.09	116, 467	14.56
Jul. 2000				
Aug. 2000	51, 275	4.59	126, 754	12.05
Sep. 2000	120, 678	3	438, 642	27.51
Oct. 2000	96, 933	2.74	592, 907	16.34
Nov. 2000	82, 779	2.28	624, 203	13.26
TOTAL	517, 914	1.45	4286, 506	12.08

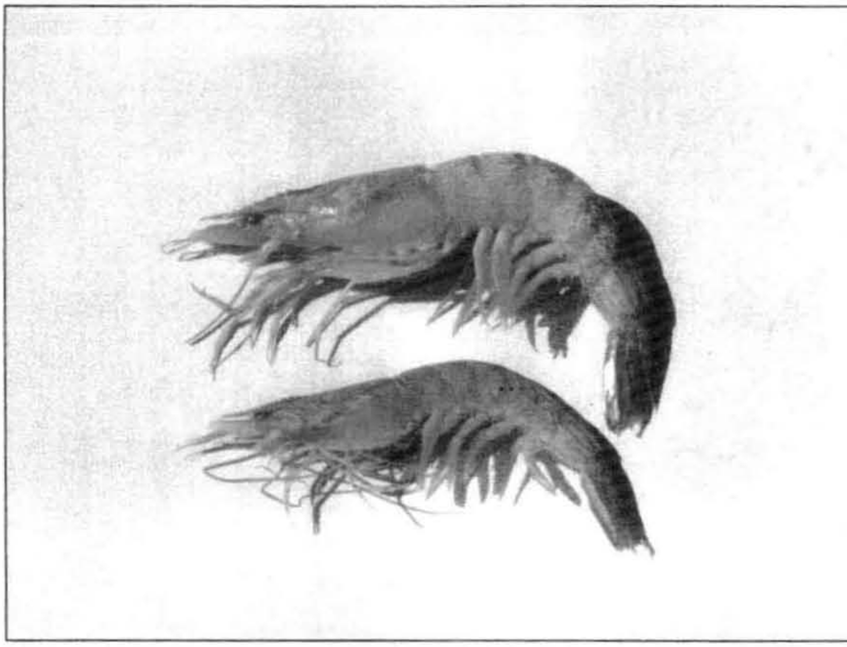

Plate 1: Male (lower) and female (upper) of *Metapenaeus affinis*

Plate 2: Catch of *M. affinis* at Versova landing centre

4.1 Size Composition:

The numbers of male and female *M. affinis* (in thousands) from offshore waters, landed by trawlers at New Ferry Wharf, grouped into size classes, raised to the monthly catch, are presented in Table 3 and 4 respectively. Similarly, those from nearshore waters, landed at Versova by trawlers are presented in Table 5 and 6 and from shallow nearshore waters, landed at Versova by hand trawlers are presented in Table 7 and 8. The data pooled for the three fishing zones were used for the estimation of growth and mortality parameters and are presented in Table 9 and 10 for male and female respectively. Separate estimates of the catch and samples from the trawlers operating in the nearshore waters could not be obtained for Dec. 99 and Jan. 2000.

From the tables it can be seen that in case of males all the size groups, 66 – 70 mm to 146 – 150 mm were available in all three fishing areas during the period of investigation, whereas in case of females, larger size groups, 166 – 170 mm to 186 – 190 mm were more frequently available in the offshore waters.

Abundance of juveniles of the species (less than 114 mm in total length) is shown in Fig. 1. It is seen that excepting for January, February and April in shallow nearshore waters, February and March in nearshore waters and February and May in offshore waters, juveniles were present in the catch. Maximum abundance of juveniles was in the post-monsoon months.

Plates 3 and 4 show the juveniles and adults of the prawn.

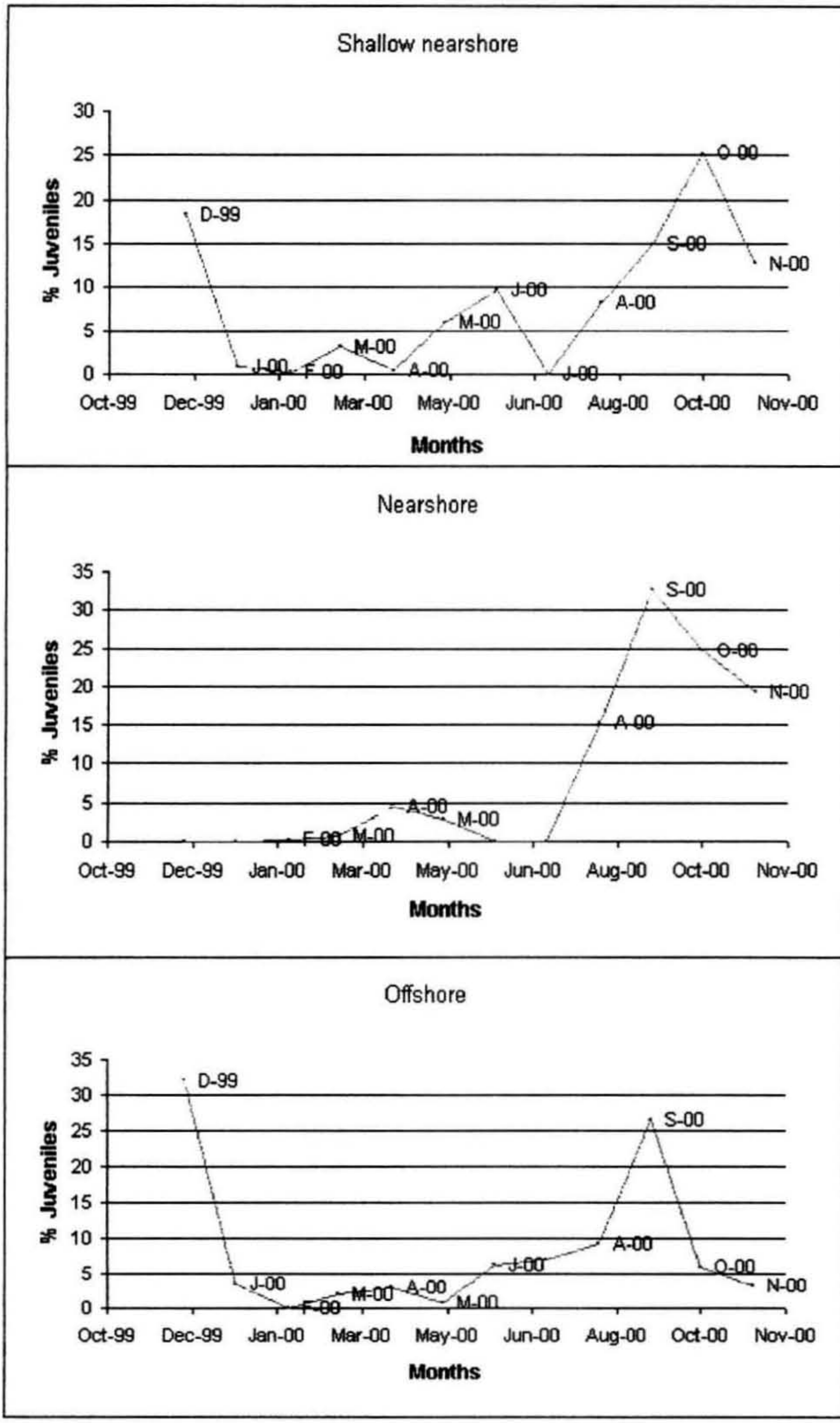

Fig. 1: Distribution of juveniles in the three fishing zones

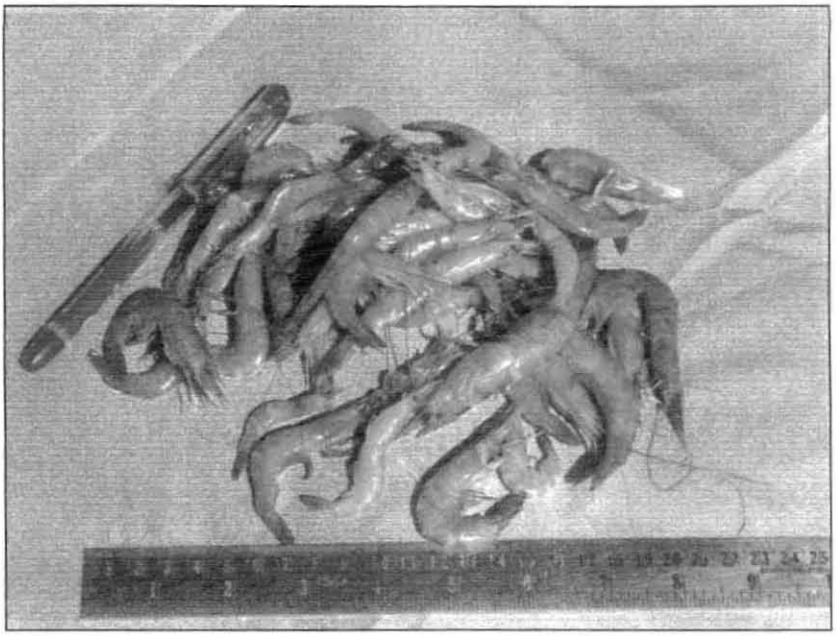

Plate 3: Juveniles of *M. affinis*

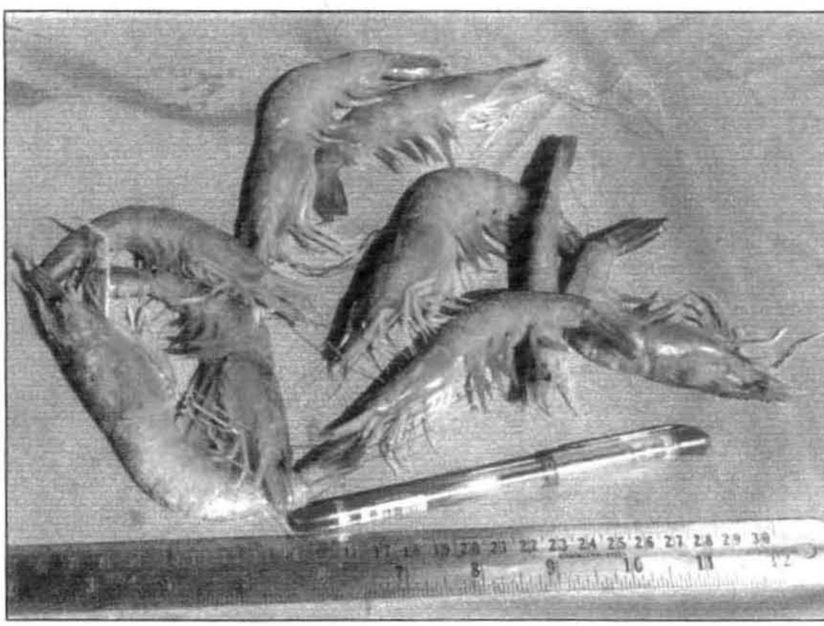

Plate 4: Adults of *M. affinis*

Table 3: Monthwise size-frequency of males (in thousands), from offshore waters

MONTH / SIZE CLASS	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00
68												
73							26.80					
78	63.12						55.58					
83				9.80			107.86					
88	245.37					6.98	73.94	17.11	9.55			
93	129.49			29.38	25.14	6.98	74.59	83.29	66.22	371.21		
98	606.64	57.56		19.58	57.81	28.30	105.14	132.36	228.30	274.19	61.97	32.87
103	716.09	133.59		116.86	125.60	14.90	84.94	199.47	262.88	190.34	453.73	151.01
108	929.48	247.76	15.49	21.87	80.38	12.97	69.08	233.37	455.31	1155.21	184.03	142.65
113	455.04	490.86	44.74	42.91	20.10	25.49	138.78	139.90	528.49	1002.72	335.20	79.69
118	838.49	438.25	198.09	153.51	65.32	129.69	100.84	81.47	438.54	832.71	1389.98	280.77
123	530.20	308.38	191.49	306.54	109.34	136.29	73.64	79.89	57.33	1766.52	1058.24	308.36
128	639.08	215.61	118.38	292.67	178.88	134.34	69.03	56.45	207.90	872.60	1362.76	339.48
133	287.98	16.86	80.44	271.35	91.44	78.45	17.77	36.29	61.95	203.93	484.64	287.08
138	122.68		33.54	63.76	83.91	10.98	3.96	10.33	12.52	525.86	60.09	81.16
143	42.61	5.62	3.84	31.90	22.96	13.97		5.70	9.55	158.33		
148			15.49	11.00					9.55			
TOTAL	**5606.26**	**1914.50**	**701.49**	**1371.13**	**860.89**	**599.33**	**1001.96**	**1075.65**	**2348.10**	**7353.63**	**5390.65**	**1703.06**

Table 4: Monthwise size-frequency of females (in thousands), from offshore waters

MONTH / SIZE CLASS	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00
68												
73							12.41					
78	80.07						32.74		12.52			
83	272.68						32.74			45.97		
88	206.30			29.38			35.38	33.36	34.59	229.84	30.98	
93	160.14			9.80	7.53	13.97	140.39	46.65	47.77	367.75	151.25	59.16
98	772.33			39.18	27.61	20.96	71.73	145.24	122.87	274.19	30.98	48.29
103	533.56	81.65		55.81	123.12	30.75	115.71	211.30	184.82	272.56	92.95	79.40
108	937.55	109.50		39.18	70.37	0.47	72.76	130.33	206.90	1504.96	61.97	76.88
113	1142.04	586.42		21.87	40.18	0.47	171.15	166.96	638.21	1703.38	455.53	118.12
118	1753.72	728.79	50.82	65.60	15.04	13.44	108.29	125.26	795.37	1228.06	1155.27	166.40
123	1143.76	776.57	109.77	42.76		9.32	68.76	128.80	888.27	1797.50	2506.74	345.10
128	1008.71	1188.84	298.23	102.69	38.00	157.31	19.16	66.29	259.94	2333.68	1599.20	479.80
133	1210.20	476.74	381.33	205.12	67.81	197.45	120.37	120.20	347.91	1758.29	1812.50	448.97
138	1655.12	436.50	540.60	366.45	153.89	248.14	147.33	120.37	654.05	2099.56	1882.15	447.93
143	612.99	392.73	500.73	562.25	258.09	161.45	146.72	63.03	223.38	1389.06	971.08	527.11
148	942.51	303.92	298.58	498.74	244.50	111.06	145.64	32.20	123.88	1371.46	579.47	418.19
153	1375.35	263.10	201.37	412.29	211.74	147.13	76.29	59.26	74.46	691.76	273.31	61.20
158	588.05	168.23	103.45	162.53	212.13	166.68	103.90	34.27	95.50	394.15	213.21	63.24
163	192.57	69.84		163.49	191.37	103.93	44.57	12.66		266.86		
168	49.42	153.47		41.79	93.53	49.90	29.41	6.96		393.26		
173	126.23			45.04	7.53	94.48	21.00			88.93		15.70
178	49.42		9.92	9.89		6.98	9.18	1.26		142.99		
183	189.35				7.53			5.70		147.24		
188	63.12					12.51	12.41					
TOTAL	**15065.18**	**5736.31**	**2494.81**	**2873.85**	**1769.94**	**1546.37**	**1738.04**	**1510.09**	**4710.43**	**18501.46**	**11816.60**	**3355.49**

Table 5: Monthwise size-frequency of males (in thousands), from nearshore waters

MONTH SIZE CLASS	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00
68												
73									10.11			
78									86.46	113.83	117.70	75.25
83						4.05			57.09	455.37	314.40	75.25
88					64.70				10.11	227.71	268.45	150.51
93				25.60	80.88	36.38			75.01	341.54	163.64	225.76
98			5.71	8.53	48.53	28.30			114.19	113.83	314.40	150.51
103				25.60	80.88	4.05			281.92	341.54	399.03	150.51
108					97.04	141.44			530.45	796.91	327.30	301.01
113			9.25	17.06	145.58	56.58			642.73	683.08	457.86	376.27
118			17.15	51.19	80.88	125.28			338.36	1366.15	641.70	301.01
123			69.97	121.21	80.88	64.66			157.62	341.54	373.25	150.51
128			121.45	89.13	16.19	24.25				113.83	163.65	150.51
133			49.28	46.47							163.65	150.51
138			26.40	2.05		40.41						
143				4.11								
148												
TOTAL			**299.22**	**390.95**	**695.57**	**525.39**			**2304.05**	**4895.32**	**3705.02**	**2257.61**

Table 6: Monthwise size-frequency of females (in thousands), from nearshore waters

MONTH / SIZE CLASS	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00
68												
73									10.11	113.83	58.85	75.25
78					16.19				10.11			
83			5.71		32.35				116.79	113.83	150.77	150.51
88				8.53	16.19	4.05			59.69			
93					32.35				96.57	227.71	209.62	301.01
98			17.15	17.06	32.35	40.41			160.22	455.37	268.45	75.25
103			5.71	8.53	16.19	20.2			200.65	683.08	399.03	225.76
108			5.71		64.7	88.91			137.3	227.71	176.53	526.78
113					48.53	105.07			338.26	113.83	281.33	150.51
118			9.25	17.06	80.88	141.44			368.98	1138.32	327.3	225.76
123			18.51	23.22	32.35	133.36			457.75	1024.61	818.25	225.76
128			29.94	44.41	80.88	80.83			197.1	683.08	445	225.76
133			35.67	39.99	80.88	181.85			104.08	683.08	432.1	526.78
138			72.15	61.47	97.04	40.41				227.71	393.44	
143			101.27	112.68	48.53	60.63				227.71	301.52	376.27
148			81.41	114.42		96.99					91.92	
153			99.92	69.69	16.19	101.03					91.92	225.76
158			29.95	31.76	32.35	101.03					137.87	
163			9.25	14.69	32.35						45.95	150.51
168				2.05								
173												
178						4.05						
183				2.05								
188												
TOTAL			**521.61**	**567.61**	**760.3**	**1200.26**			**2257.61**	**5919.85**	**4629.85**	**3461.66**

Table 7: Monthwise size-frequency of males (in thousands), from shallow nearshore waters

MONTH / SIZE CLASS	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00
68	2.79											
73	2.79			1.14					4.20	9.39	44.08	2.20
78	7.32						3.02		8.41		29.63	3.15
83	11.98			1.70		5.89	6.05		8.41	28.18	35.19	13.72
88	26.45	1.29		3.22		8.18	18.16		4.20	18.79	18.77	9.47
93	41.54	1.29	1.01	3.78		9.95	27.24			18.79	25.44	27.29
98	38.31		0.51	4.77		18.91	21.19			28.18	16.17	22.51
103	22.67	1.29		7.09	0.81	9.70	9.08		8.41	28.18	63.74	39.93
108	14.96	0.27	2.03	8.82	4.15	14.70	6.05		21.02	18.79	40.75	14.68
113	7.74	10.61	3.55	4.77	7.25	24.49	6.05		25.21	159.73	90.02	34.87
118	12.23	15.54	2.54	9.66	5.11	14.40	9.08			93.96	91.50	40.22
123	2.29	8.30	6.51	21.24	8.05	2.48	15.13			37.59	103.50	31.05
128	7.10	3.51	5.90	14.09	7.79	3.64	6.05		4.20		35.69	46.94
133	0.77	2.72	2.80	0.93	0.54	0.66	9.08				15.69	13.86
138	4.11	1.42	0.39	2.05		1.20	3.02				5.92	
143			0.77			0.66	3.02					
148				0.38								
TOTAL	**203.06**	**46.24**	**26.02**	**83.63**	**33.70**	**114.86**	**142.24**		**84.07**	**441.58**	**616.10**	**299.88**

Table 8: Monthwise size-frequency of females (in thousands), from shallow nearshore waters

MONTH / SIZE CLASS	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00
68	2.79											
73	6.34			1.14						9.39	29.63	13.45
78	8.36			0.95			6.05		12.61	9.39	9.75	5.21
83	7.50	1.29		3.40		6.00	9.08		4.20	9.39	21.61	18.78
88	20.16			7.23		2.24	18.16		12.61	18.79	22.11	13.86
93	38.19	2.59	0.51	4.35	0.54	7.78	18.16		12.61	9.39	15.69	8.51
98	30.17	2.59		4.77		9.53	9.08		4.20	46.97	37.78	9.60
103	31.28	4.15	0.51	3.82		12.47	18.16		29.42	18.79	31.86	20.31
108	29.20	1.55		3.27	1.21	7.86	12.11		25.22	9.39	33.10	16.72
113	23.34	1.55	1.01	8.40	1.21	14.69	12.11		33.63	9.39	55.32	16.88
118	11.17	4.15	3.04	3.61	1.21	19.45	6.05		25.22	65.76	26.80	15.78
123	8.37	9.71	6.51	9.37	2.14	14.10	9.08		12.61	75.17	65.70	30.88
128	5.43	11.40	5.85	4.94	2.56	10.62			8.41	65.76	67.93	48.28
133	2.44	12.42	9.85	16.19	4.57	7.25	3.02		8.41	75.17	81.51	35.82
138	5.03	14.38	8.20	9.89	5.52	11.16	3.02			9.39	69.17	34.97
143	3.73	8.81	9.75	9.18	8.33	7.36	3.02			9.39	25.57	48.73
148	0.92	2.97	4.62	17.80	4.70	3.06				9.39	14.08	23.62
153	1.52	2.85	3.10	11.15	6.60	9.19					13.58	33.07
158	4.63		0.77	5.43	3.78	3.72	3.02					5.35
163	1.12	2.85	1.28	6.52	1.63	2.52						4.26
168			0.77	1.65	0.54	3.83						
173												
178												
183		1.29										
188						0.66						
TOTAL	**241.71**	**84.57**	**55.79**	**133.05**	**44.52**	**153.50**	**130.14**		**189.16**	**450.89**	**621.19**	**404.08**

Table 9: Monthwise size-frequency of males (in thousands), pooled for the three fishing zones

MONTH / SIZE CLASS	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00
68	2.78											
73	2.78			1.13			26.79		14.31	9.38	44.07	2.19
78	70.43						58.60		94.87	113.83	147.32	78.40
83	11.97			11.49		9.93	113.91		65.50	483.84	349.59	88.97
88	271.82	1.28		3.22	64.69	15.16	92.09	17.11	23.86	246.49	287.22	159.97
93	171.02	1.28	1.01	58.77	106.02	53.31	101.83	83.29	141.22	731.54	189.08	253.04
98	644.94	57.56	6.21	32.88	106.34	75.50	126.32	132.36	342.48	416.19	392.54	205.88
103	738.76	134.88		149.55	207.29	28.64	94.02	199.47	553.20	560.05	916.49	341.44
108	944.44	248.02	17.51	30.68	181.57	169.11	75.13	233.37	1006.78	1970.91	552.08	458.34
113	462.78	501.47	57.53	64.73	172.92	106.55	144.83	139.89	1196.42	1845.53	883.06	490.83
118	850.72	453.79	217.78	214.35	151.31	269.37	109.91	81.47	776.89	2292.82	2123.18	622.00
123	532.49	316.68	267.97	448.98	198.27	203.42	88.77	79.89	214.95	2145.64	1534.99	489.90
128	646.17	219.12	245.73	395.88	202.85	162.22	75.08	56.45	212.10	986.43	1562.10	536.92
133	288.75	19.57	132.52	318.74	91.98	79.10	26.84	36.28	61.94	203.93	663.97	451.45
138	126.79	1.42	60.32	67.85	83.91	52.58	6.98	10.33	12.51	525.85	66.01	81.15
143	42.61	5.62	4.61	36.00	22.95	14.62	3.02	5.70	9.55	158.33		
148			15.38	11.38					9.55			
TOTAL	**5809.25**	**1960.69**	**1026.67**	**1845.63**	**1590.10**	**1239.51**	**1144.12**	**1075.61**	**4736.13**	**12690.46**	**9711.70**	**4260.48**

Table 10: Monthwise size-frequency of females (in thousands), pooled for the three fishing zones

MONTH / SIZE CLASS	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00
68	2.78											
73	6.34			1.13			12.41		10.10	123.21	88.47	88.70
78	88.42			0.94	16.18		38.79		35.23	9.38	9.75	5.20
83	280.17	1.28	5.71	3.40	32.34	5.99	41.81		120.99	169.18	172.38	169.28
88	226.45			45.13	16.18	6.28	53.54	33.35	106.89	248.63	53.09	13.86
93	198.32	2.58	0.50	14.14	40.41	21.75	158.55	46.64	156.95	604.83	376.55	368.68
98	802.50	2.58	17.15	61.00	59.95	70.90	80.80	145.24	287.29	776.52	337.21	133.14
103	564.84	85.80	6.21	68.15	139.30	63.42	133.87	211.29	414.89	974.42	523.84	325.47
108	966.75	111.05	5.71	42.44	136.27	97.23	84.87	130.33	369.41	1742.04	271.59	620.37
113	1165.38	587.97	1.01	30.26	89.92	120.22	183.25	166.95	1010.09	1826.59	792.17	285.50
118	1764.89	732.94	63.11	86.26	97.12	174.33	114.34	125.26	1189.56	2432.14	1509.36	407.94
123	1152.12	786.28	134.79	75.34	34.49	156.78	77.83	66.28	1358.63	2897.28	3390.68	601.73
128	1014.14	1200.23	334.02	152.04	121.44	248.75	19.15	120.20	465.45	3082.51	2112.12	753.83
133	1212.64	489.16	426.85	261.30	153.25	386.54	123.39	120.37	460.39	2516.53	2326.10	1011.56
138	1660.15	450.87	620.95	437.81	256.45	299.71	150.35	63.03	654.04	2336.65	2344.75	482.90
143	616.72	401.54	611.75	684.10	314.95	229.43	149.74	32.19	223.38	1626.15	1298.17	952.10
148	943.43	306.89	384.61	630.95	249.19	211.10	145.64	59.25	123.88	1380.84	685.47	441.81
153	1376.86	265.95	304.39	493.12	234.53	257.35	76.29	34.26	74.46	691.76	378.81	320.03
158	592.67	168.23	134.17	199.71	248.24	271.43	106.92	12.66	95.50	394.14	351.08	68.58
163	193.69	72.69	10.52	184.70	225.33	106.44	44.56	6.95		266.86	45.95	154.76
168	49.42	153.47	0.77	45.49	94.06	53.73	29.40			393.25		
173	126.23			45.04	7.52	94.48	20.99			88.93		15.70
178	49.42		9.92	9.88		11.02	9.18	1.25		142.99		
183	189.34	1.28		2.05	7.52			5.70		147.24		
188	63.11					13.16	12.41					
TOTAL	**15306.78**	**5820.79**	**3072.14**	**3574.38**	**2574.64**	**2900.04**	**1868.08**	**1509.99**	**7157.13**	**24872.07**	**17067.54**	**7221.14**

4.2 Dimensional Relationships:

Measurements of total length, carapace length, total weight, tail weight and meat weight of the specimens collected every month from the three fishing areas were taken in the laboratory and pooled together to find out their dimensional relationships. In case of males 431 individuals in the size range of 66-152 mm and in case of females, 654 individuals in the size range of 69-175 mm were examined. The relationships and the coefficient of correlations are presented in Table 11.

Table 11: Dimensional relationships in male and female *M. affinis*.

RELATION	NO. OF SPECIMENS		RELATIONSHIP		COEFFICIENT OF CORRELATION 'r'	
	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE
Total Length - Total Weight	431	654	$W = 0.000003323\ L^{3.13}$	$W = 0.000001395\ L^{3.32}$	0.97	0.98
Total Length - Carapace Length	431	654	CL = -1.792 + 0.2373 L	CL = -6.751+ 0.2919 L	0.97	0.97
Carapace Length - Total Weight	431	654	$W = 0.00093\ CL^{2.84}$	$W = 0.0018\ CL^{2.61}$	0.97	0.98
Total Weight - Tail Weight	431	654	Tl.W = -0.145 + 0.65 W	Tl.W = 0.216 + 0.59 W	0.99	0.98
Total Weight - Meat Weight	431	654	W = 0.401 + 1.87 M.W	W = 0.27 + 1.94 M.W	0.98	0.99

4.3 Dimorphic Characters:

Male and female prawns were easily distinguishable due to clear sexual dimorphism in size and external morphological characters. Males were observed to be smaller in size and pinkish brown in colour whereas females grew much larger in size and were pale to dark green in colour. Males could also be distinguished by the presence of petasma on the first pair of pleopods and appendix masculina on the second pair of pleopods. In case of females, presence of thelycum between the last three pairs of thoracic legs distinguished them from males.

Male reproductive system:

Internal organs are comprised of the testes, vasa deferentia and terminal ampoules. Petasma forms the external sex organ. Petasma and appendix masculina are shown in Plates 5 and 6 respectively.

Testes:

The testes are unpigmented, translucent and irregular in shape. They are situated in the thoracic region, lying above the posterior half of the dorsal surface of the hepatopancreas and beneath the pericardial sinus and the heart. Each testis has projections from its main axis, an anterior lobe, about six lateral lobes and a single short posterior lobe. In the young males, the testes are extremely delicate and transparent structures, but as they mature they grow in size and become somewhat opaque.

Vasa deferentia:

Each vas deferens arises from the posterior margin of the main axis of the testes and opens to the exterior through genital pores located medially on the coxae of the fifth pereopods. Each consists of a short narrow proximal section passing into a thickened medial portion having double flexure, which forms a relatively long narrow tube terminating in a dilated muscular region the 'ductus ejaculatous' or 'terminal ampoule'. This distal region forms the spermatophore and a white sticky fluid. The spermatophore, which is a sac like structure, contains sperm cells that are transferred by male to female.

Petasma:

The petasma of the male is abdominal in origin and formed by the modification of the right and left endopodites of the first pair of pleopods. Each half of the petasma is formed of two main lobes of the endopodites, namely median and lateral lobes. The lateral lobe is composed of two foldings, the dorsal or anterior and the ventral or posterior lobules. In the adult prawn the two halves are generally joined together in the median line on the dorsal side by a number of minute hooks or cincinnuli arranged in a zipper like manner. On the ventral side the two halves are usually closely approximated but not united together.

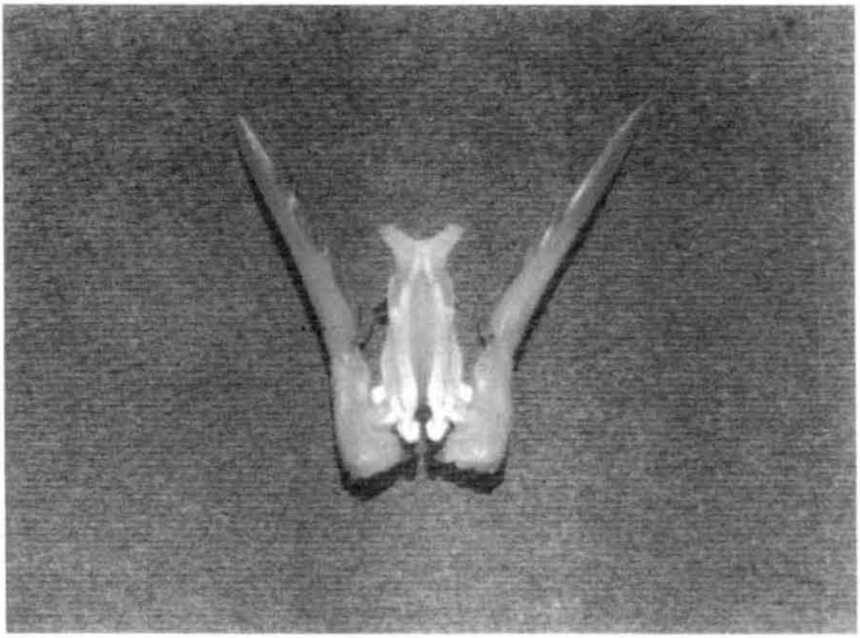

Plate 5: Petasma of *M. affinis*

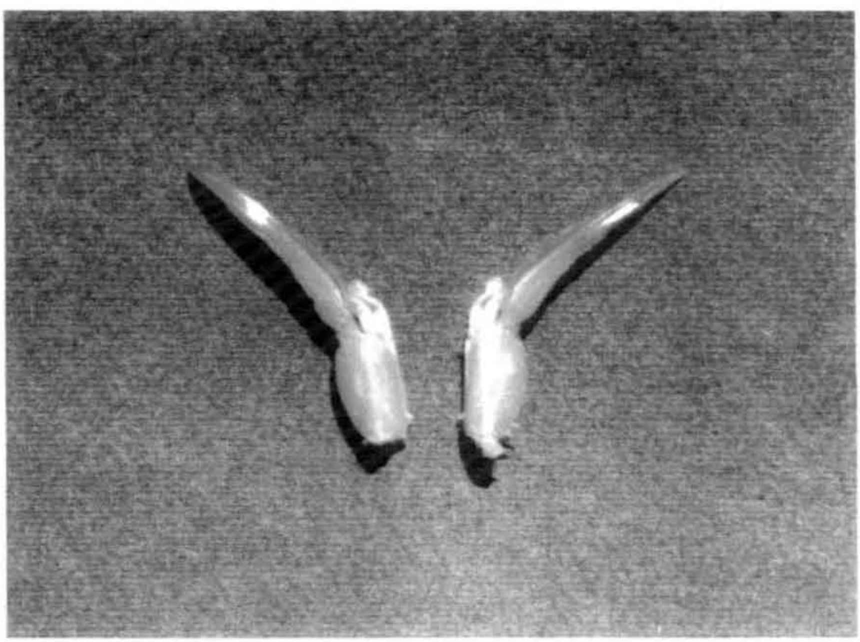

Plate 6: Appendix masculina of *M. affinis*

Female reproductive system

It consists of paired ovaries, paired oviducts and a single thelycum. Plates 7 and 8 show the lateral and ventral views of thelycum of *M. affinis*.

Ovaries:

They are partly fused and bilaterally symmetrical bodies. In mature female ovary extends for almost its entire length, from the cardiac region of the stomach to the last abdominal segment. The paired anterior lobe lies in the cephalothoracic region and extends anteriorly to the base of the antennae. The anterior lobes on the either side lie close to the oesophagus and cardiac region of the stomach. The middle lobe is also paired and lies in between the epigastric tooth and the lower border of the carapace. This lobe shows 6-7 fingerlike projections laterally. The anterior and middle lobes are situated dorsal to the cephalothorax. The posterior lobe of the ovary lies in the abdominal region, laterally on each side of the intestine and extends dorsally from the first abdominal segment to the middle of the sixth segment. The ovaries are transparent, thread like structures in immature condition, but become green to dark green, when fully mature. Mature ovary is clearly visible through the exoskeleton. When preserved in formalin, ovary changes to dark orange colour. The two halves of the ovary are connected by two commissures, one at the base of the anterior lobe and the other near the tip of the posterior lobe.

Oviducts:

These are short, thin and narrow tubes, arising from the penultimate lobule of the middle lobe and run down to the external genital opening in the coaxae of the fifth pereopod of the respective sides.

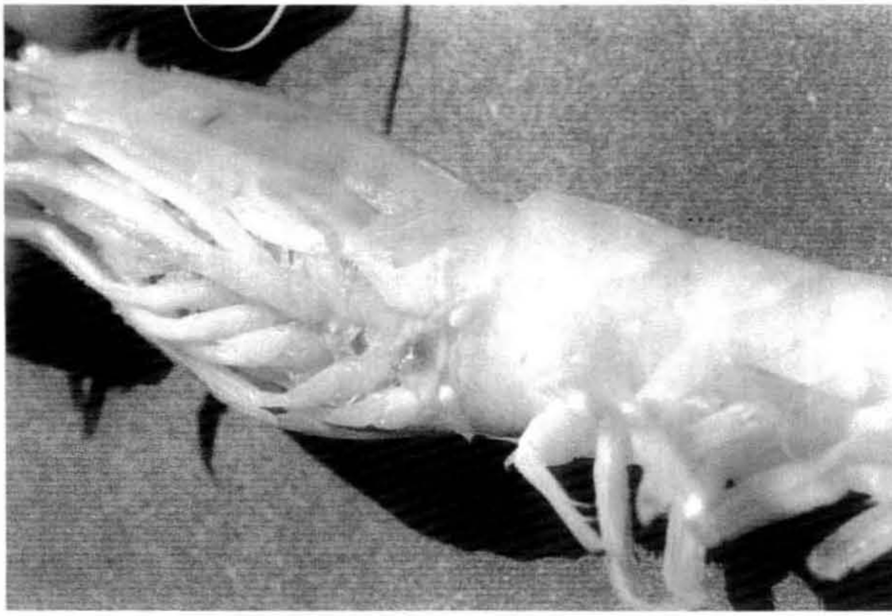

Plate 7: Thelycum of *M. affinis* (lateral view)

Plate 8: Thelycum of *M. affinis* (ventral view)

Thelycum:

Thelycum is the external sex organ in female, which is thoracic in origin and is formed by the modifications of sternal plates of somites XII, XIII and XIV. It provides an attachment for the spermatophore received from the male during copulation. The adult thelycum consists of an anterior median plate and the lateral plates situated on 7^{th} and 8^{th} thoracic sternites respectively. Thelycum in *M. affinis* was observed to be closed type, consisting of two flaps or lateral plates, separated by a median slit that opens into paired seminal receptacle where spermatophores are deposited during mating.

In the present work, ovaries were examined macroscopically as well as microscopically for the determination of their state of maturity. The ovaries were distinguished into five distinct stages:

1. Stage I or immature ovary – Ovaries were thin and translucent, unpigmented and invisible through the exoskeleton. Formalin preserved ovaries looked white in colour. Microscopic examination revealed small spherical ova with clear cytoplasm and conspicuous nuclei. The ova were 0.02 - 0.08 mm in size. Stage I ovary and transverse sections of the ovary showing immature ova are presented in Plates 9, 10 and 11.
2. Stage II or early maturing ovary – ovaries were slightly pigmented, yellowish green in colour and visible through the exoskeleton. Anterior and middle lobes were more developed. Ova showed opaque yolk granule formation and were larger than the immature stock. Size of the ova ranged from 0.06 – 0.12 mm in diameter. Stage II ovary and transverse sections of

the ovary showing early maturing ova are presented in Plates 12, 13 and 14.

3. Stage III or late maturing – ovary green in colour and clearly visible through the exoskeleton. Development of anterior and middle lobes was complete. The ova looked opaque under microscope due to accumulation of yolk. Ova were irregular in shape, being spherical, oval or oblong. Their size ranged from 0.14 – 0.32 mm. Stage III ovary and transverse sections of the ovary showing late maturing ova are presented in Plates 15, 16 and 17.

4. Stage IV or mature - Ovary is dark green in colour and clearly visible through the exoskeleton and indicated an all-round increase in girth. It occupied almost all the available space in the cephalothorax. Microscopic evaluation showed that ova are large and opaque, with transparent peripheral region. But rod-like peripheral bodies, radiating from the opaque central region, described in the mature ova of some penaeid prawns (Hudinaga, 1942; King, 1948 and Tuma 1967) were not observed in this species. Size of the ova ranged from 0.2 – 0.36 mm. Stage IV ovary and transverse sections of the ovary showing mature ova are presented in Plates 18, 19 and 20.

5. Stage V or spent-recovering ovary – ovaries become flaccid and revert to the immature state. They are opaque and creamy white in appearance. Dissected and teased section under the microscope showed large number of small immature ova and some scattered degenerating ova. Transverse sections of a

spent ovary showing immature and degenerating ova are shown in Plates 21 and 22.

Plate 9: Immature (stage I) ovary

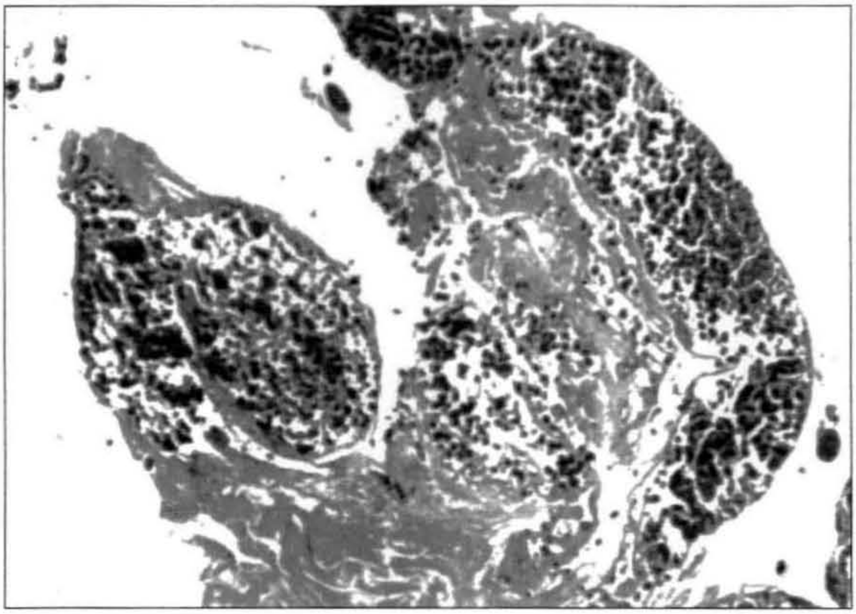

Plate 10: T. S. of immature ovary (H & E, x100)

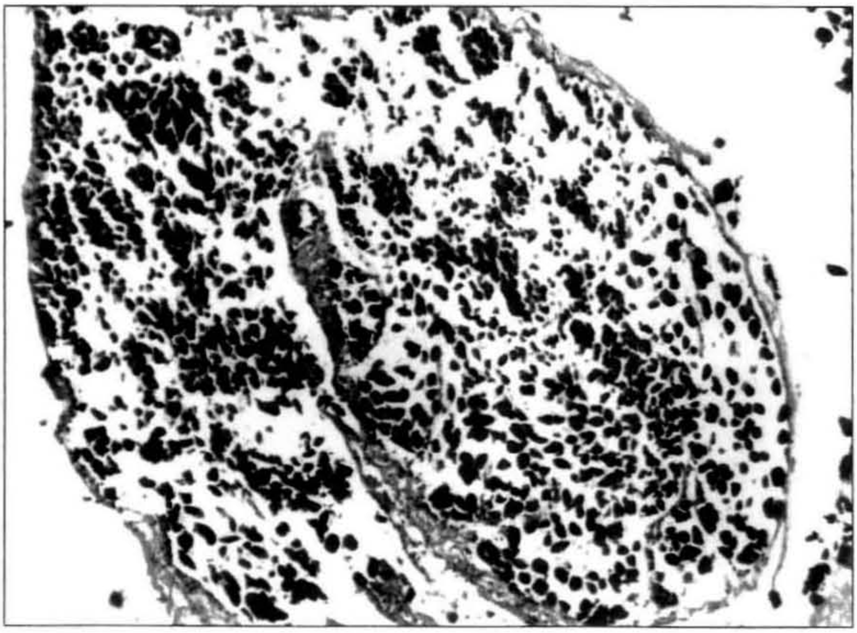

Plate 11: T. S. of immature ovary (H & E, x400)

Plate 12: Early maturing (stage II) ovary

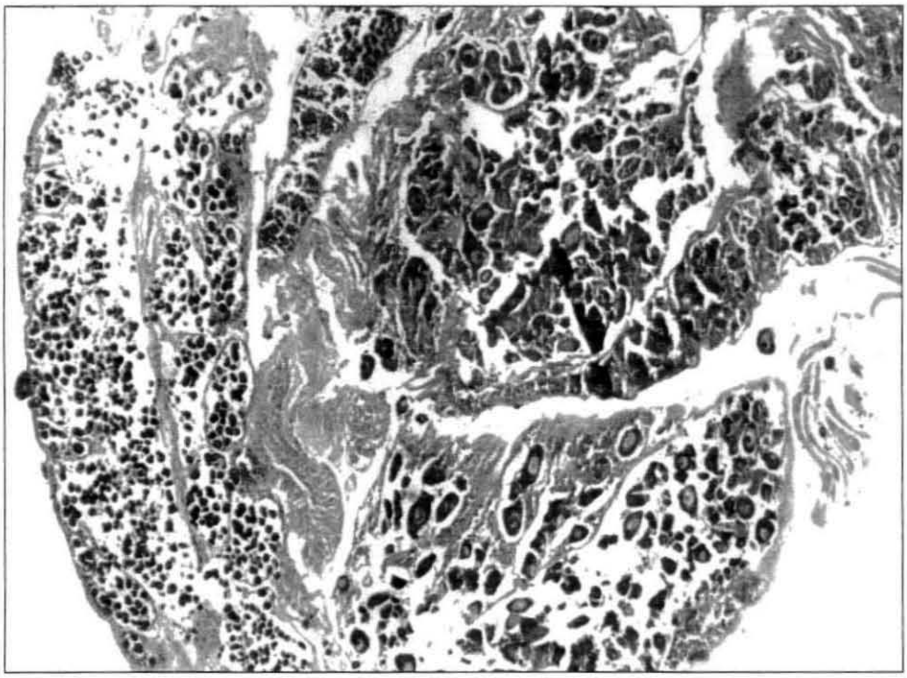

Plate 13: T. S. of early maturing ovary (H & E, x100)

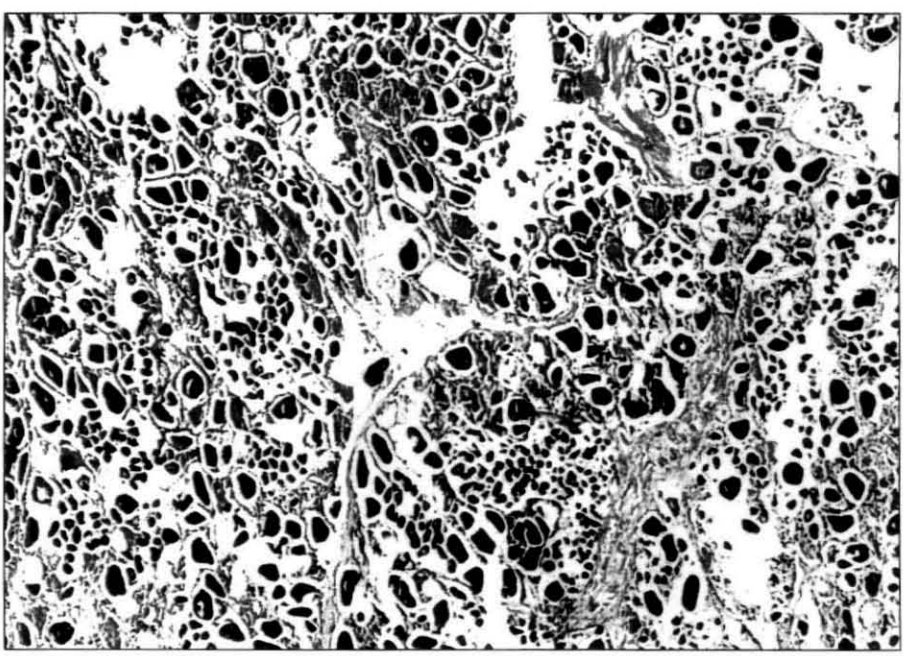

Plate 14: T. S. of early maturing ovary (H & E, x400)

Plate 15: Late maturing (stage III) ovary

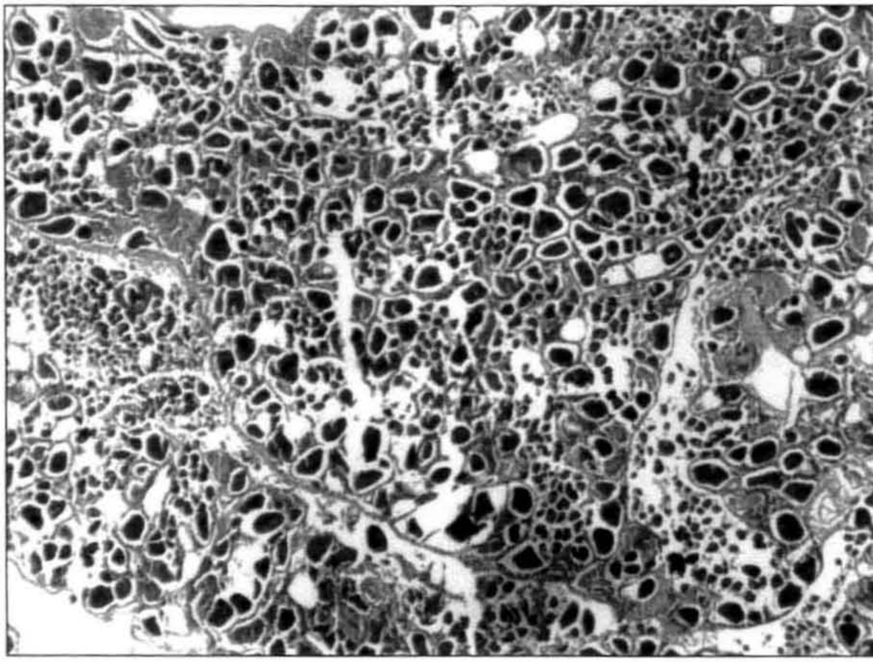

Plate 16: T. S. of late maturing ovary (H & E, x100)

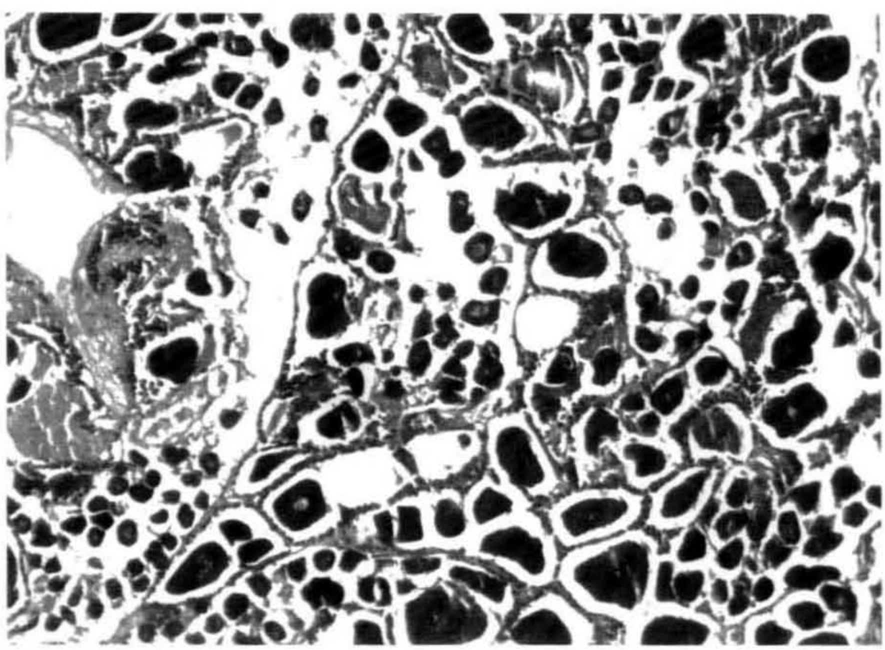

Plate 17: T. S. of late maturing ovary (H & E, x400)

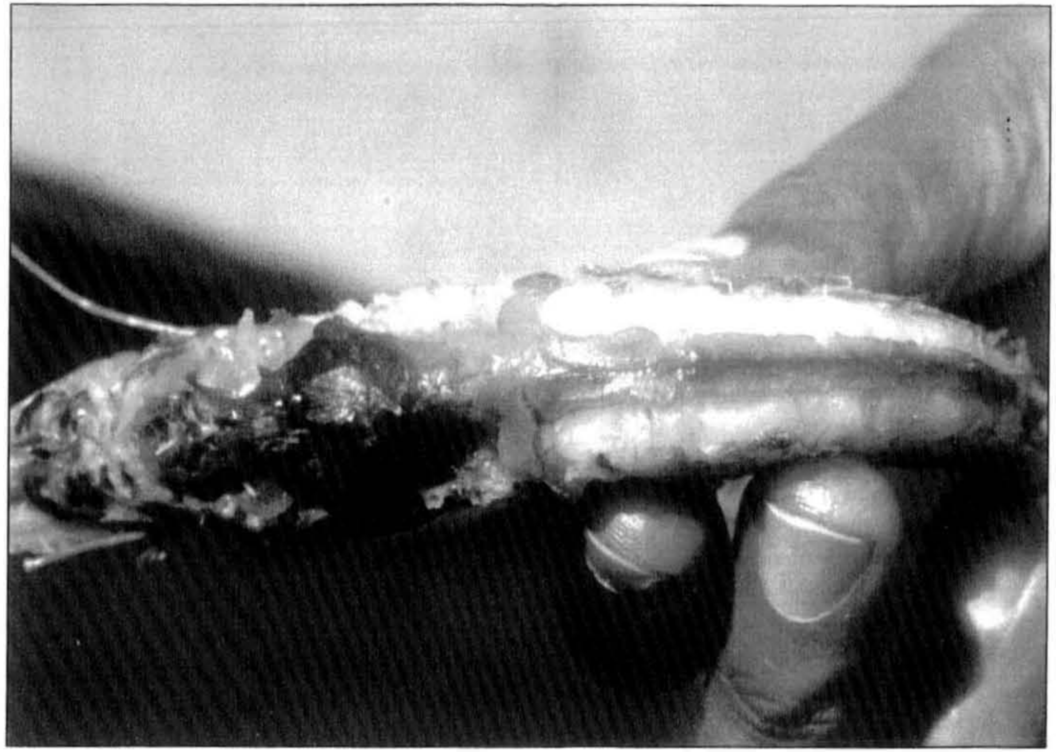

Plate 18: Mature or Stage IV ovary

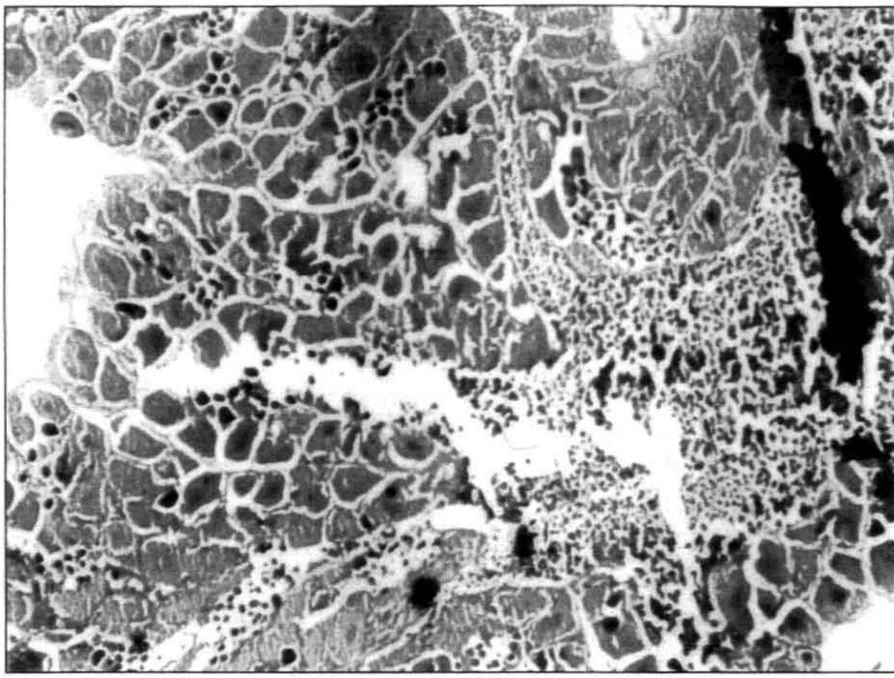

Plate 19: T. S. of mature ovary (H & E, x100)

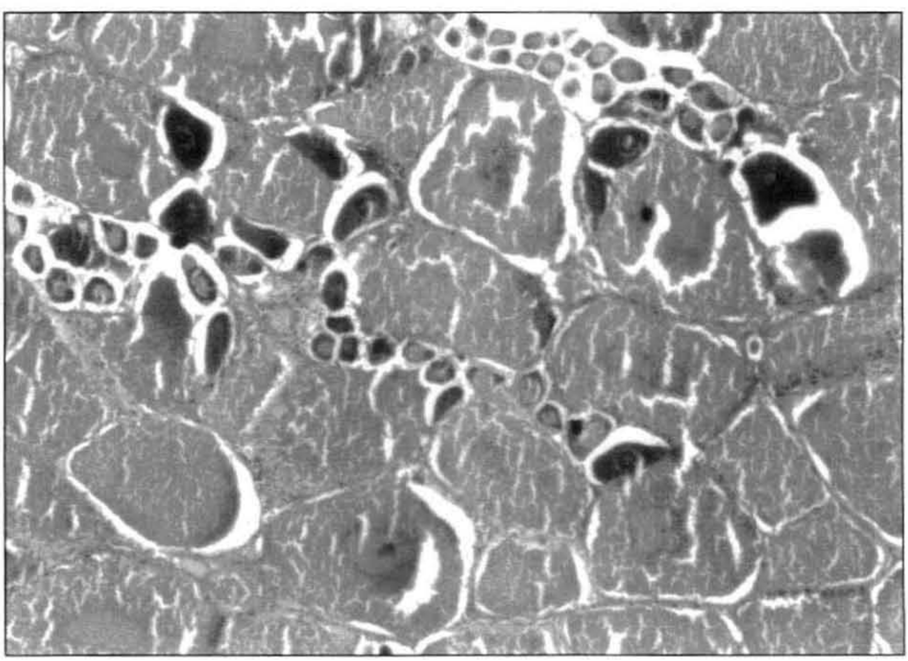

Plate 20: T. S. of mature ovary (H & E, x400)

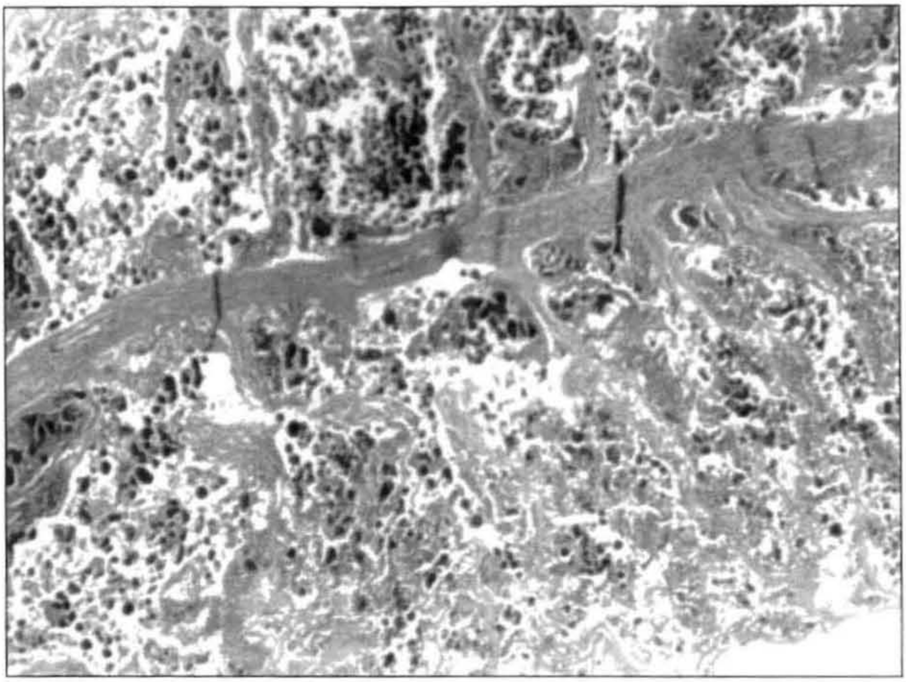

Plate 21: T. S. of spent ovary (H & E, x100)

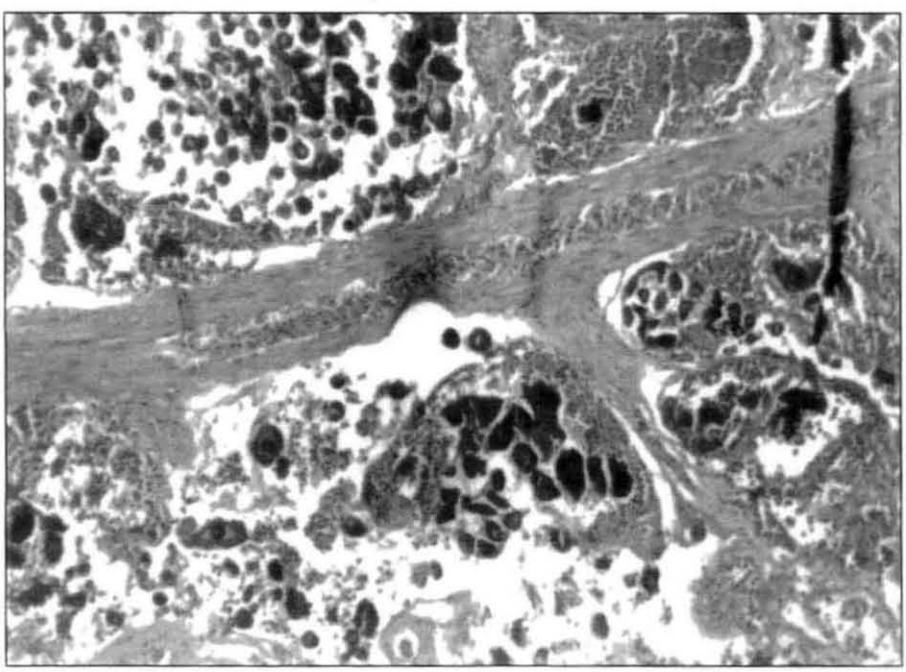

Plate 22: T. S. of spent ovary (H & E, x400)

4.4 Length-at-Maturity:

The details of calculation of length-at-maturity for males pooled from all the three fishing areas is presented in Table 12 and Fig. 2. The calculations for females from offshore, nearshore, shallow nearshore waters and the pooled data are given in Table 13, 14, 15 and 16 respectively. The graphs are presented in Fig 3, 4, 5 and 6.

Males with united petasma and clearly visible spermatophores in their terminal ampoules were considered as mature. Males in the size range of 68 – 98 mm were considered for the estimation of length at maturity since prawns larger than 98 mm were all found to be mature. The smallest male with united petasma was 83 mm in length; the proportion of males with united petasma increased to 0.5 (50%) at 87 mm therefore the length-at-maturity (L_m) for males was 87 mm.

In case of females, in offshore waters, the smallest female observed in mature condition (stage III ovary) was 93 mm in length and the length-at-maturity was estimated to be 129 mm. In nearshore waters, the length-at-maturity was estimated to be 104 mm whereas in shallow nearshore waters it was 114 mm.

Upon pooling the data from the three areas and then estimating the length-at-maturity, for the females was found to be 114 mm.

Table 12: Details of estimation of length-at-maturity of males, pooled for the three fishing zones

SIZE	NO. OF MALES	MATURE MALES	PROPORTION MATURE	ADJUSTED PROPORTION MATURE	ln[(1-p)/p]	P
68	2	0	0.00	0.00		
71	2	0	0.00	0.00		
74	1	0	0.00	0.00		
77	1	0	0.00	0.00		
80	3	0	0.00	0.00		
83	4	1	0.25	0.25	1.098	0.254
86	9	4	0.44	0.44	0.241	0.429
89	14	9	0.64	0.64	-0.575	0.624
92	12	9	0.75	0.75	-1.098	0.785
95	10	9	0.90	0.90	-2.197	0.89
98	12	12	1.00	1.00		

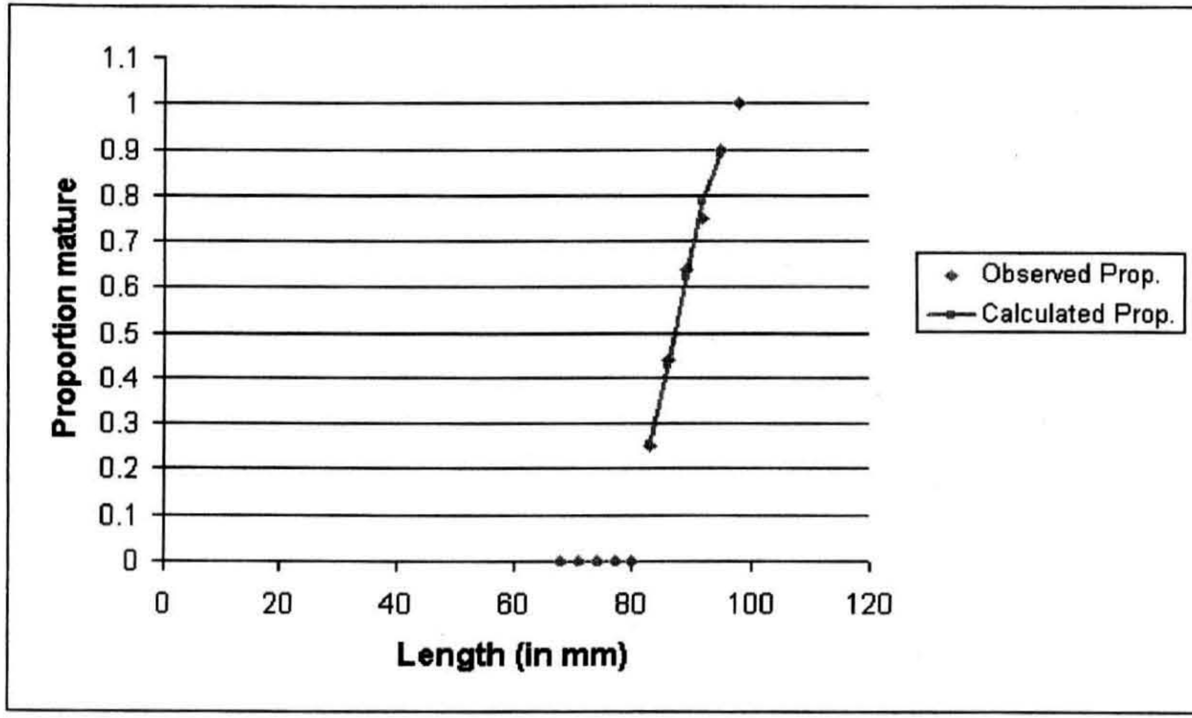

Fig. 2: Length-at-maturity of males, pooled for the three fishing zones

Table 13: Details of estimation of length-at-maturity of females in offshore waters

SIZE	NO. OF FEMALES	MATURE FEMALES	PROPORTION MATURE	ADJUSTED PROPORTION MATURE	ln[(1-p)/p]	P
78	125321	1980	0.016	0.016	4.132	
83	351382	1980	0.006	0.006	5.731	
88	599892	0	0.000	0.000		
93	1004392	5166	0.005	0.005	5.268	0.126
98	1553382	86020	0.055	0.055	2.837	0.159
103	1781634	280043	0.157	0.157	1.679	0.199
108	3210861	1439528	0.448	0.448	0.207	0.245
113	5044312	2678501	0.531	0.531	-0.124	0.299
118	6206062	3841291	0.619	0.619	-0.485	0.358
123	7017900	4870197	0.694	0.694	-0.819	0.423
128	7551837	5295244	0.701	0.701	-0.853	0.49
133	7146892	5407351	0.757	0.757	-1.134	0.557
138	8752089	6736551	0.770	0.770	-1.207	0.622
143	5808612	5010152	0.863	0.863	-1.837	0.684
148	5070166	3892492	0.768	0.768	-1.196	0.739
153	3847260	3215039	0.836	0.836	-1.626	0.788
158	2309329	1696916	0.735	0.735	-1.019	0.829
163	1045293	896184	0.857	0.857	-1.793	0.864
168	817740	728700	0.891	0.891	-2.102	0.893
173	398914	297936	0.747	0.747	-1.082	0.916
178	229651	179700	0.782	0.782	-1.280	0.935
183	349819	349819	1.000	1.000		
188	93200	93200	1.000	1.000		

Table 14: Details of estimation of length-at-maturity of females in nearshore waters

SIZE	NO. OF FEMALES	MATURE FEMALES	PROPORTION MATURE	ADJUSTED PROPORTION MATURE	ln[(1-p)/p]	P
103	1610569	459079	0.285	0.339	0.666	0.473
108	1279045	705719	0.552	0.657	-0.650	0.6
113	1037526	675735	0.651	0.775	-1.240	0.715
118	2392224	1634194	0.683	0.813	-1.472	0.808
123	2900407	2289631	0.789	0.940	-2.751	0.876
128	2056572	1442965	0.702	0.835	-1.625	0.922
133	2405402	2020166	0.840			
138	1541590	1256404	0.815			
143	2139998	1349013	0.630			
148	1117464	867999	0.777			
153	1503834	1109737	0.738			
158	602530	453356	0.752			
163	335974	241441	0.719			
168	2052	2052	1.000			
173	4045	4045	1.000			
178						
183	2052	2052	1.000			

Table 15: Details of estimation of length-at-maturity of females in shallow nearshore waters

SIZE	NO. OF FEMALES	MATURE FEMALES	PROPORTION MATURE	ADJUSTED PROPORTION MATURE	ln[(1-p)/p]	P
93	118310	6978	0.059	0.059	2.770	0.194
98	154697	11857	0.077	0.077	2.489	0.25
103	170604	47535	0.279	0.279	0.951	0.32
108	139619	85787	0.614	0.614	-0.466	0.4
113	177531	129956	0.732	0.732	-1.005	0.48
118	182255	140247	0.770	0.770	-1.206	0.57
123	243644	201641	0.828	0.828	-1.569	0.65
128	231188	190155	0.823	0.823	-1.533	0.72
133	256667	228145	0.889	0.889	-2.079	0.78
138	170731	148482	0.870	0.870	-1.898	0.84
143	133878	110234	0.823	0.823	-1.540	0.88
148	81164	63060	0.777	0.777	-1.248	0.91
153	81074	72423	0.893	0.893	-2.125	0.93
158	26689	24830	0.930	0.930	-2.592	0.95
163	20180	20180	1.000	1.000		
168	6792	5752	0.847	0.847	-1.710	

Table 16: Details of estimation of length-at-maturity of females, pooled for the three fishing zones

SIZE	NO. OF FEMALES	MATURE FEMALES	PROPORTION MATURE	ADJUSTED PROPORTION MATURE	ln[(1-p)/p]	P
93	1989961	12144	0.006	0.007	4.977	
98	2928732	97877	0.033	0.037	3.245	0.27
103	3562807	786657	0.221	0.248	1.110	0.335
108	4629525	2231034	0.482	0.541	-0.164	0.408
113	6259369	3484192	0.557	0.625	-0.510	0.484
118	8780541	5615732	0.640	0.718	-0.934	0.562
123	10161951	7361469	0.724	0.813	-1.470	0.637
128	9839597	6928364	0.704	0.790	-1.327	0.705
133	9808961	7655662	0.780	0.876	-1.955	0.766
138	10464410	8141442	0.778	0.873	-1.929	0.817
143	8082488	6469399	0.800	0.898	-2.179	0.859
148	6268794	4823551	0.769	0.863	-1.845	0.893
153	5432168	4397199	0.809	0.908	-2.295	0.919
158	2938548	2175102	0.740	0.831	-1.591	0.939
163	1401447	1157805	0.826	0.927	-2.545	0.955
168	826584	736504	0.891	1.000		

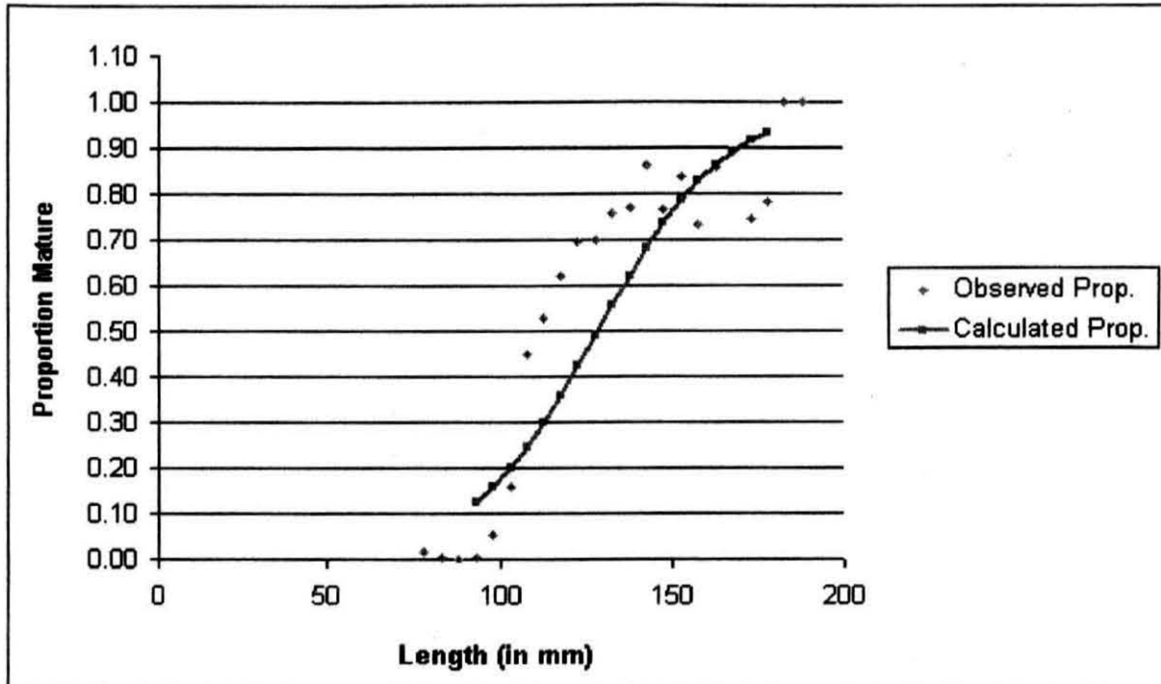

Fig. 3: Length-at-maturity of females in offshore waters

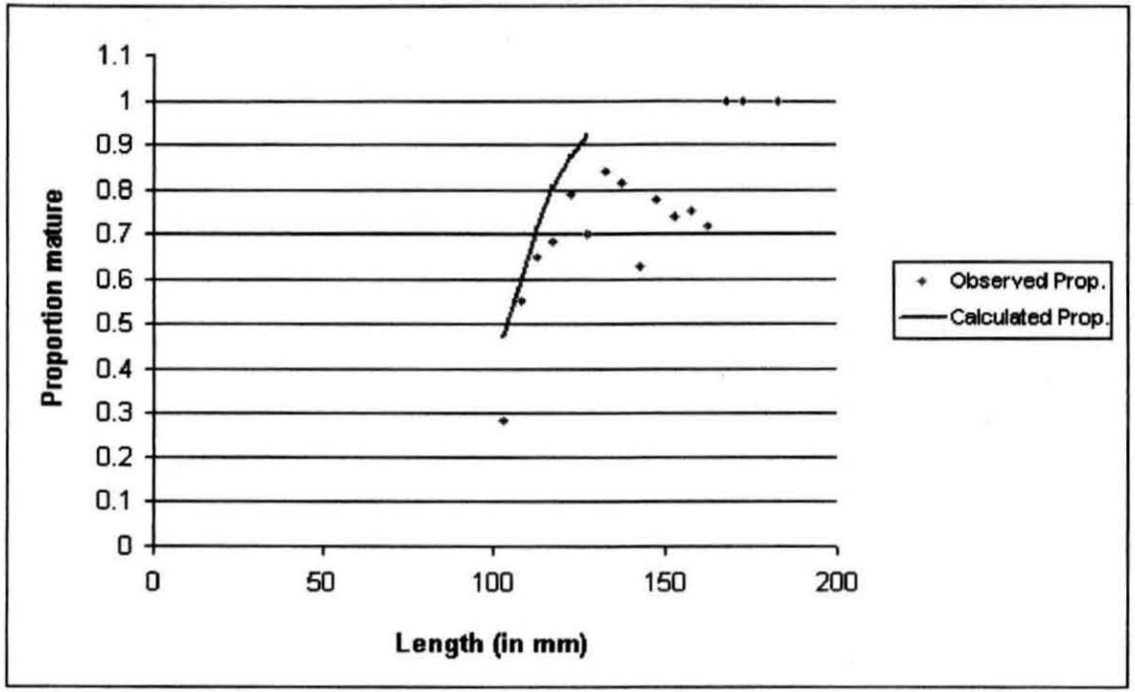

Fig. 4: Length-at-maturity of females in nearshore waters

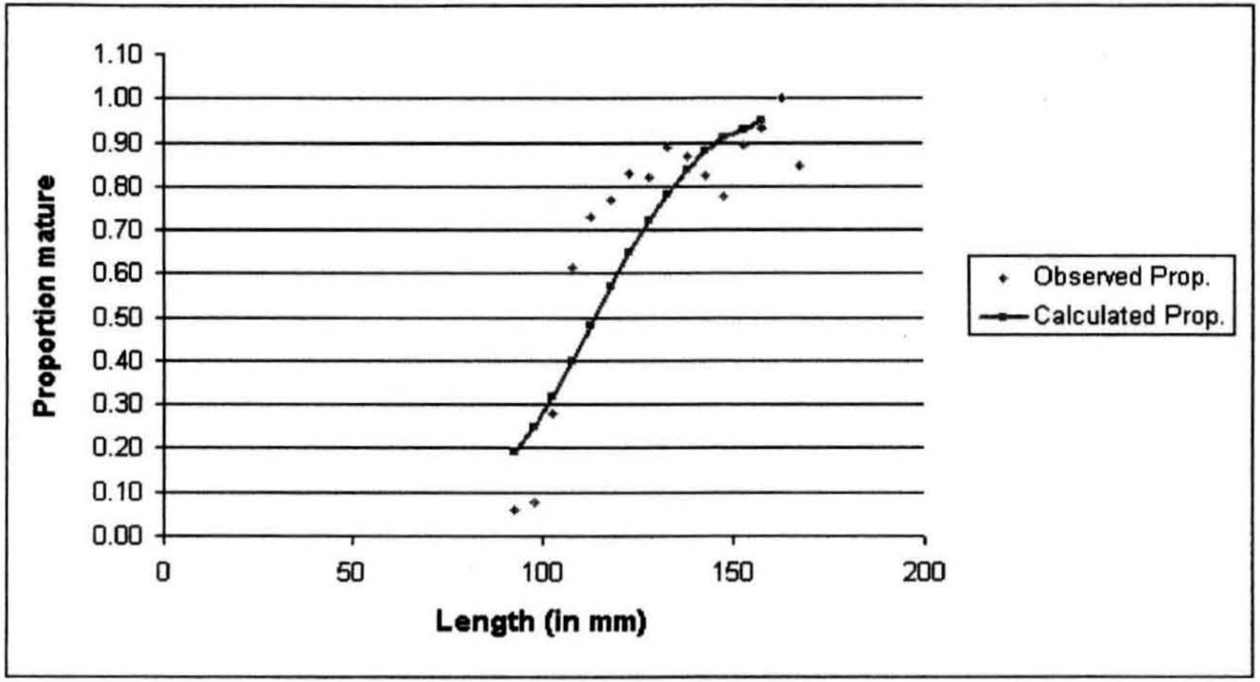

Fig. 5: Length-at-maturity of females in shallow nearshore waters

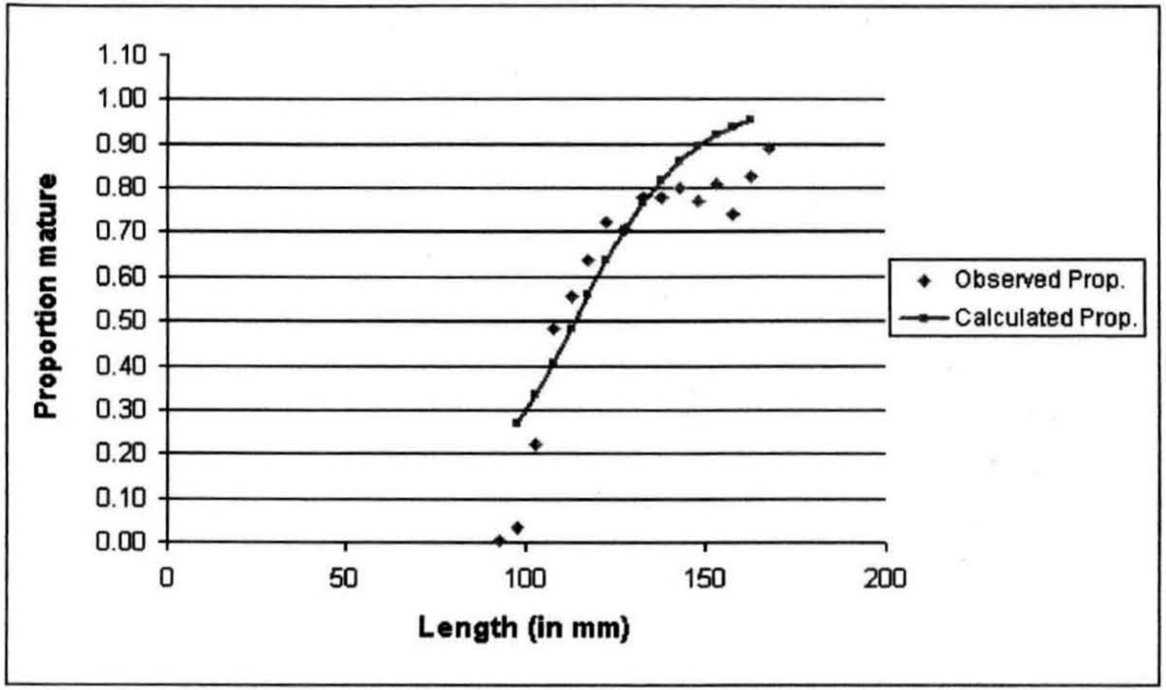

Fig. 6: Length-at-maturity of females, pooled for the three fishing zones

4.5 Monthwise Maturity Distribution:

Monthwise maturity distribution in case of females is presented in Table 17, 18 and 19 in offshore, nearshore and shallow nearshore waters respectively and in Table 20 pooled for the three fishing zones. In case of offshore waters maximum percentage of immature prawns (stage I and II) was found in the month of August, mature prawns (stage III and IV) in the month of November and spent females in the month of May. In case of nearshore waters no conclusions were drawn due to inadequacy of data in December '99 and January 2000. In shallow nearshore waters maximum percentage of immature females was in the month of December. The mature females were maximum in the month of April and spent females in the month of February.

Monthwise percentage of mature females in the three fishing zones is presented in Table 21. It is seen that mature females occurred in all the months but the percentage of mature females showed two peaks in all the three fishing zones. In case of shallow nearshore waters, the primary peak was in April (80.6 %) and the secondary in October (74.7%). The same was also seen in nearshore waters with primary peak in May (72.3%) and secondary in September (65.3%). In case of offshore waters the mature females showed a primary peak in November (81%) and a secondary one in April (73.2%). When the data were pooled for all the three fishing zone, it was found that the primary peak of maturation and spawning of females lies in the month of April (77.2%) and the secondary one in October (71.2%) and November (71.3%).

Fig. 7 shows the distribution of mature and ripe females in the three fishing zones.

Table 17: Monthwise maturity distribution of females in offshore waters (% in parenthesis)

STAGE MONTH	I	II	III	IV	V	TOTAL
DEC	29 (10.9)	82 (30.9)	83 (31.3)	53 (20)	18 (6.8)	265
JAN	3 (1.2)	37 (15)	88 (35.7)	82 (33.3)	36 (14.6)	246
FEB	1 (.03)	28 (10.2)	135 (49.4)	61 (22.3)	48 (17.6)	273
MAR	17 (6.2)	38 (13.9)	116 (42.3)	77 (28.1)	26 (9.4)	274
APR	2 (1)	38 (20.7)	82 (44.8)	52 (28.4)	9 (4.9)	183
MAY	0 (0)	53 (20.3)	67 (25.7)	89 (34.2)	51 (19.6)	260
JUN	24 (9.7)	53 (21.6)	95 (38.7)	58 (23.6)	15 (6.1)	245
JUL	10 (3.9)	91 (35.9)	98 (38.7)	53 (20.9)	1 (.03)	253
AUG	8 (4.7)	66 (39)	55 (32.5)	35 (20.7)	5 (2.9)	169
SEP	17 (5.4)	42 (13.4)	117 (37.3)	96 (30.6)	41 (13)	313
OCT	2 (1)	31 (18.6)	95 (57)	28 (16.8)	10 (6)	166
NOV	5 (2)	23 (12)	91 (49)	60 (32)	6 (3)	185
TOTAL	118 (4.2)	582 (20.6)	1122 (39.6)	744 (26.3)	266 (9.4)	2832

Table 18: Monthwise maturity distribution of females in nearshore waters (% in parenthesis)

STAGE MONTH	I	II	III	IV	V	TOTAL
DEC						
JAN						
FEB	6 (7)	21 (27)	28 (36.3)	17 (22)	5 (6)	77
MAR	4 (3.8)	16 (15.3)	47 (45)	26 (25)	11 (10)	104
APR	2 (4.2)	12 (25.5)	23 (48.9)	10 (21.2)	0 (0)	47
MAY	2 (2.2)	19 (21.8)	33 (37.9)	30 (34.4)	3 (3.4)	87
JUN						
JUL						
AUG	22 (17)	37 (28.6)	51 (39.5)	19 (14.7)	0 (0)	129
SEP	4 (7.6)	14 (26.9)	26 (50)	8 (15.3)	0 (0)	52
OCT	8 (9.1)	20 (22.9)	30 (34.4)	22 (25.2)	7 (8)	87
NOV	5 (10.8)	15 (32.6)	18 (39.1)	6 (13)	2 (4)	46
TOTAL	53 (8.4)	154 (24.5)	256 (40.7)	138 (21.9)	28 (4.4)	629

Table 19: Monthwise maturity distribution of females in shallow nearshore waters (% in parenthesis)

STAGE MONTH	I	II	III	IV	V	TOTAL
DEC	71 **(35.3)**	71 **(35.3)**	40 **(19.9)**	10 **(4.9)**	8 **(3.9)**	**201**
JAN	8 **(7)**	24 **(21)**	32 **(28.3)**	46 **(40.7)**	3 **(2.6)**	**113**
FEB	2 **(1.5)**	39 **(30.9)**	54 **(42.8)**	23 **(18.2)**	8 **(6.3)**	**126**
MAR	31 **(16.9)**	49 **(26.7)**	50 **(27.3)**	52 **(28.4)**	1 **(0.05)**	**183**
APR	2 **(2.1)**	15 **(16.1)**	43 **(46.2)**	32 **(34.4)**	1 **(1)**	**93**
MAY	16 **(10.1)**	54 **(34.1)**	63 **(39.8)**	17 **(10.7)**	8 **(5)**	**158**
JUN	8 **(18.6)**	22 **(51.1)**	13 **(30.2)**	0 **(0)**	0 **(0)**	**43**
JUL						
AUG	8 **(17.7)**	10 **(22.2)**	18 **(40)**	9 **(20)**	0 **(0)**	**45**
SEP	8 **(16.6)**	6 **(12.5)**	28 **(58.3)**	6 **(12.5)**	0 **(0)**	**48**
OCT	15 **(9.6)**	18 **(11.6)**	73 **(47)**	43 **(27.7)**	6 **(3.8)**	**155**
NOV	18 **(11.1)**	29 **(18)**	85 **(52.7)**	20 **(12.4)**	9 **(5.5)**	**161**
TOTAL	187 **(14.1)**	337 **(25.4)**	499 **(37.6)**	258 **(19.5)**	44 **(3.3)**	**1326**

Table 20: Monthwise maturity distribution of females pooled for the three fishing zones (% in parenthesis)

STAGE MONTH	I	II	III	IV	V	TOTAL
DEC	100 (21.5)	153 (32.9)	123 (26.4)	63 (13.5)	26 (5.5)	465
JAN	11 (3)	61 (16.9)	120 (33.4)	128 (35.6)	39 (10.8)	359
FEB	9 (1.8)	88 (18.4)	217 (45.5)	101 (21.2)	61 (12.8)	476
MAR	52 (9.2)	103 (18.3)	213 (37.9)	155 (27.6)	38 (6.7)	561
APR	6 (1.9)	65 (20.7)	148 (47.2)	94 (30)	13 (4)	326
MAY	18 (3.5)	126 (24.9)	163 (32.2)	136 (26.9)	62 (12.2)	505
JUN	32 (11.1)	75 (26)	108 (37.5)	58 (20.1)	15 (5.2)	288
JUL	10 (3.9)	91 (35.9)	98 (38.7)	53 (20.9)	1 (.03)	253
AUG	38 (11)	113 (32.9)	124 (36.1)	63 (18.3)	5 (1.4)	343
SEP	29 (7)	62 (15)	171 (41.4)	110 (26.6)	41 (9.9)	413
OCT	25 (6.1)	69 (16.9)	198 (48.5)	93 (22.7)	23 (5.6)	408
NOV	28 (7.1)	67 (17)	194 (49.4)	86 (21.9)	17 (4.3)	392
TOTAL	358 (7.5)	1073 (22.4)	1877 (39.2)	1140 (23.8)	341 (7.1)	4789

Table 21: Monthwise percentage of mature females in the three fishing zones

MONTH	Shallow Nearshore	Nearshore	Offshore	Pooled
DEC	24.8		51.3	39.9
JAN	69		69	69
FEB	61	56.3	71.7	66.7
MAR	55.7	70	70.4	65.5
APR	80.6	70.1	73.2	77.2
MAY	50.5	72.3	59.9	59.1
JUN	30.2		62.3	57.6
JUL			59.6	59.6
AUG	60	54.2	53.2	54.4
SEP	70.8	65.3	67.9	68
OCT	74.7	59.6	73.8	71.2
NOV	65.1	52.1	81	71.3

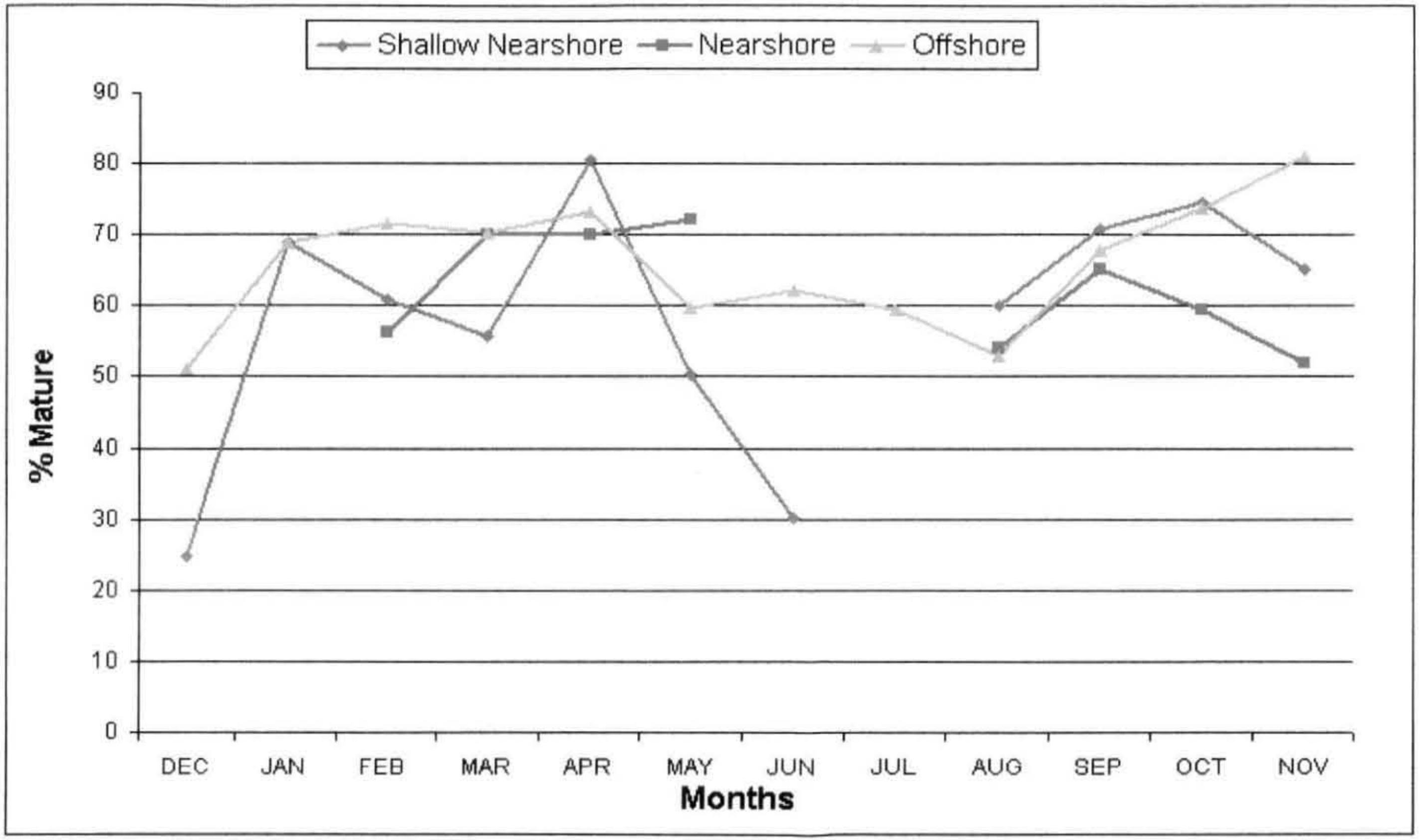

Fig. 7: Monthwise distribution of mature females in the three fishing zones

4.6 Spawning and nursery grounds:

Distribution of mature females in the three fishing grounds is presented in Fig. 8. It was observed that presence of smaller sized mature females (< 113 mm) was almost negligible in the offshore waters, whereas these size groups were abundant in the shallow nearshore and nearshore waters. As the size increased, the abundance of mature females was more in the offshore fishing grounds. Females larger than 165 mm were almost absent in the shallow nearshore and nearshore areas. This suggests that smaller prawns maturing for the first time mature in the shallower waters and then move towards deeper waters for further maturation and spawning.

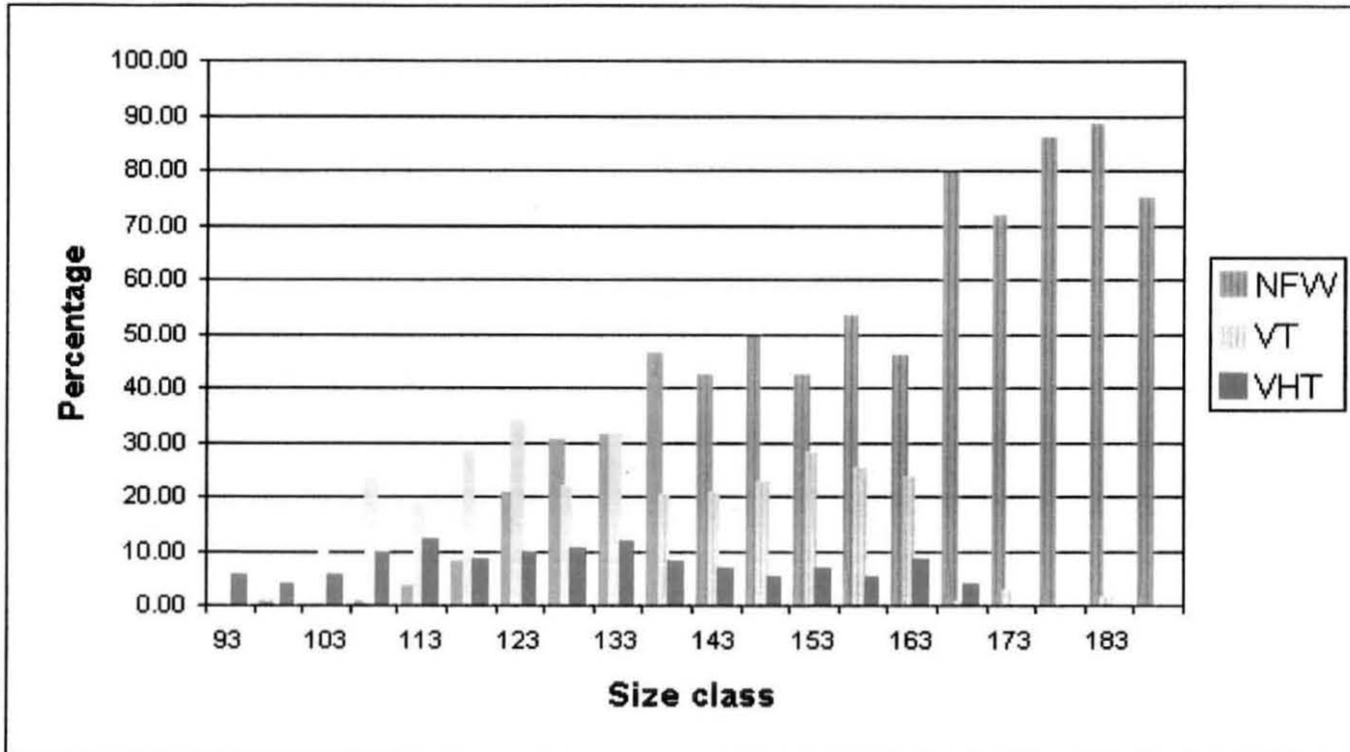

Fig. 8: Sizewise distribution of mature females in the three fishing zones

4.7 Spawning Periodicity:

In the present study, for determination of ova diameter, the mature females were preserved in formalin and their total lengths and total weights were noted. To maintain uniformity, measurements of ova were taken in the same parallel plane using ocular micrometer in which one-micrometer division was equal to 0.02 mm. Immature eggs in the size range of 0.02 – 0.08 mm, which formed the ground stock, were ignored. Distribution of ova diameters of nine ripe (stage IV) females in the size range of 105 – 152 mm is shown in Fig 9 and 10. It is seen from the figures that in the case of mature females, majority of the ova were in the size range of 0.2 to 0.36 mm and they showed a single peak. This clearly indicates that all the mature ova are shed at one instance at the time of spawning.

Modes of mature females observed in different months in the three fishing zones are presented in Tables 22, 23 and 24. A clear progression of modal size of mature females was not observed in shallow nearshore and nearshore fishing areas but in offshore waters progression of modes could be discerned. A maximum of five modes in a month were observed. The first mode was observed at 118 mm in December 1999. By using VBGF growth parameters, these females, 118 mm in size, would grow by 25 mm in two months reaching 143 mm. A corresponding mode was seen at 143 mm in February 2000. Similarly, a 143 mm sized female would grow by 15 mm in two months to reach 158 mm size in April. A corresponding mode of mature females was observed at 158 mm in April 2000. Following the modal size of 173 mm in December 1999, modes were observed at 178 mm in February 2000 and at 183 mm in April 2000. Progression of modal size of the mature females at 108 mm in March 2000, could be observed to move to 138 mm in May 2000, to 148 mm in June 2000, 153 mm in July 2000 and to 158 mm in August 2000. Another such progression was observed with a mode at 103 mm in April, which moved to 118 mm in May. Similarly, a mode at 113 mm in July grew to 123 mm in August and a mode at 108 mm in September advanced to 123 mm in October.

From the progression of modes of mature females it can be inferred that a prawn from length at maturity (114 mm) to 183 mm would spawn seven times. But there would be about four spawnings at monthly intervals until they reach 160 mm. Thereafter they would spawn at least three times at the interval of two months.

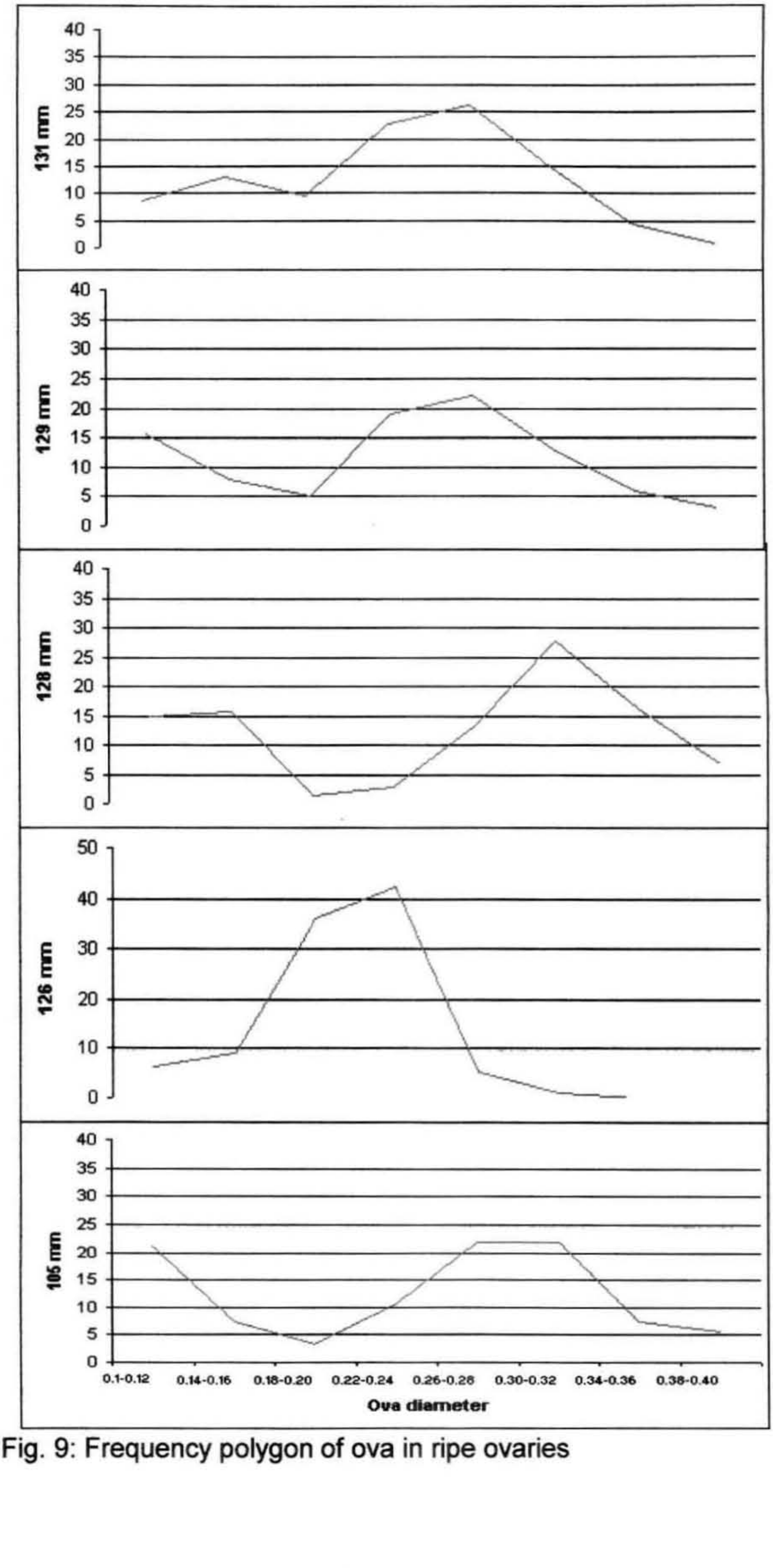

Fig. 9: Frequency polygon of ova in ripe ovaries

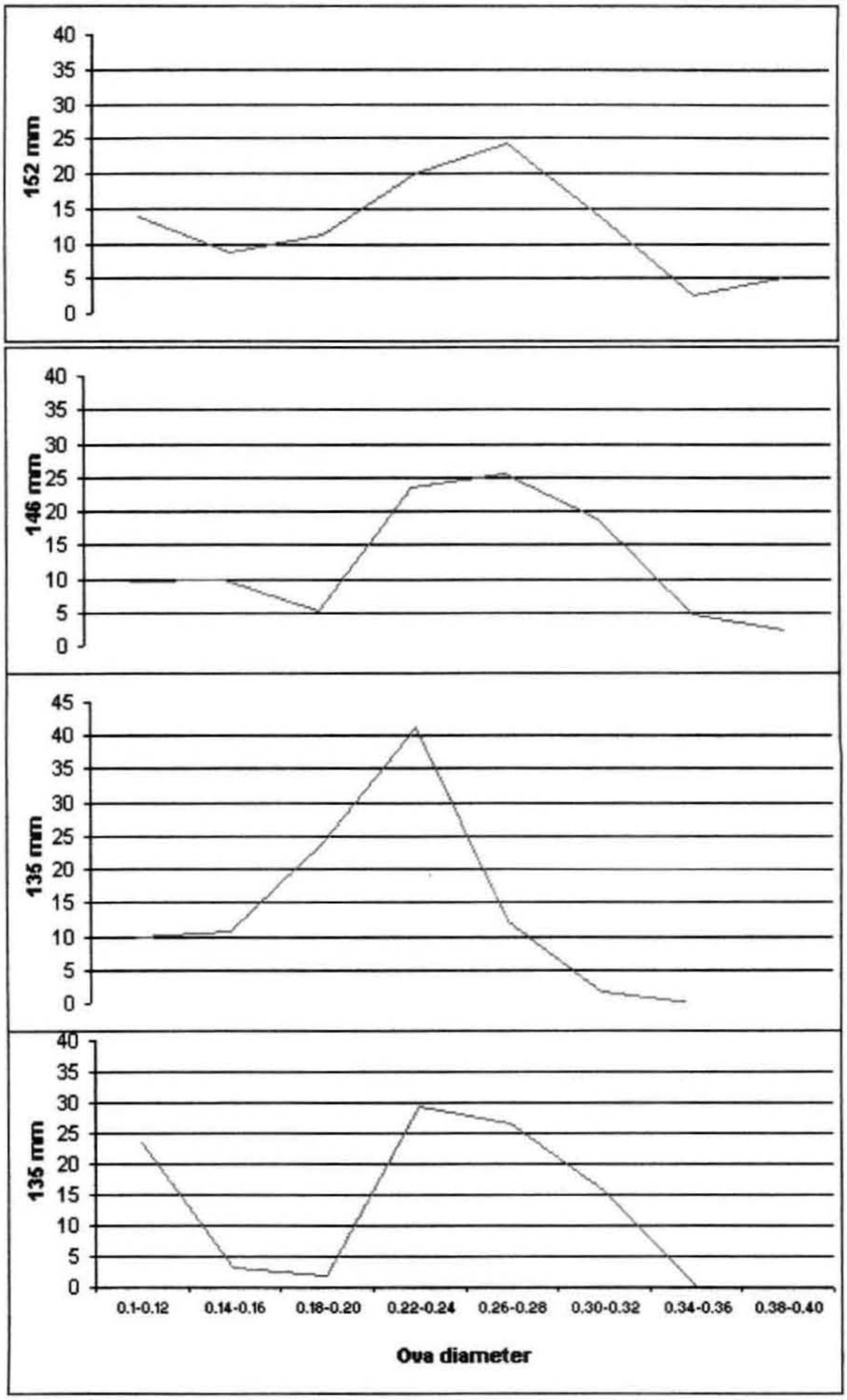

Fig. 10: Frequency polygon of ova in ripe ovaries

Table 22: Monthwise modes of mature females in offshore waters

MONTHS / SIZE	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00
68												
73												
78												
83												
88												
93												
98												
103					57813	13969						
108				9797						1043185		
113								[illegible]				
118	1061753					12971	83475					
123									[illegible]		1298827	
128		896694								2008810		
133												
138	925446					163827			592082	1590291	1820178	
143			387640		204374							492202
148				381301			121918					
153	1312244							58009				
158					197088				86982			
163												
168										393259		
173	126230						21005					15701
178			9923									
183	189345				7526			5703		147245		
188						12506	12413					

Table 23: Monthwise modes of mature females in nearshore waters

MONTHS SIZE	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00
68												
73												
78												
83												
88												
93												
98												
103												
108						76784						225761
113												
118					64696							
123						125284			341908	796951	654579	
128												
133												376268
138					97071						347492	
143			691506									
148				97659								
153												225761
158						101034						
163					32348							
168												
173												
178						4045						
183				2052								
188												

Table 24: Monthwise modes of mature females in shallow nearshore waters

MONTHS SIZE	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00
68												
73												
78												
83												
88												
93												
98												
103												
108												16722
113	8766								29422		49394	
118						13332						
123				5364			9078					
128												
133			6270	12552						75172	73733	
138	5033	11790				6892						
143					6985							48726
148												
153				11155		7877						
158	4627						3024					
163			1281									
168												
173												
178												
183												
188		1299				657						

4.8 Sex Ratio:

Monthwise ratio of males and females in the three fishing zones, shallow nearshore, nearshore and offshore areas and pooled for the three zones have been presented in Table 25, 26, 27 and 28 respectively. In shallow nearshore waters, there is a significant difference in sex ratio for the entire study period in favour of females, but in the months of December, April, June, September and October it was non significant at 95% confidence limit. In case of nearshore waters also the difference in sex ratio was non significant in the months of April, August, September, October and November and significant in the months of February, March and May. In offshore waters there was a significant difference in all the months. The proportion of females was considerably higher than males. Pooling the catches of the three zones gave a significant difference in sex ratio in favour of females in all the months at 95% confidence limits.

Sizewise sex ratios of males and females in the three fishing zones is presented in Table 29, 30 and 31, it was seen that the difference in sex ratio was not significant in the smaller length groups. However, there was a significant difference in sex ratio after 130 mm length. Percentage of females was higher in larger size groups since female prawns were seen to grow much larger in size as compared to males. In shallow nearshore waters, there was a significant difference in sex ratio in 96 – 100 mm size class with the proportion of males higher than females. Higher proportion of males was also seen in size classes 111 – 120 mm. In nearshore waters, proportion of males was seen to be significantly higher in size classes 106 – 115 mm. In offshore waters the difference in sex ratio was not significant upto 125 mm after which it was significantly in favour of females. On pooling the data from the three zones (Table 32) it was seen that proportion of males was higher upto 125 mm but significantly higher proportion was seen in 106 – 110 mm and 116 – 120 mm length classes.

In smaller size groups the difference in sex ratio was not significant and in lengths larger than 125 mm it was significantly in favour of females. Males larger than 150 mm were not noticed in any of the three fishing areas.

Male to female ratio in the shallow nearshore area was 1:1.32, in nearshore waters it was 1:1.32, in offshore waters it was 1:2.33, and the same pooled for the three fishing zones was 1:1.77.

Table 25: Monthwise sex ratio in shallow nearshore waters

MONTHS	TOTAL PRAWNS	NO. OF FEMALES	% OF FEMALES	NO. OF MALES	% OF MALES	SEX RATIO	χ^2 VALUE	SIGNIFICANCE
Dec	375	201	53.6	174	46.4	1:1.17	1.94	NS*
Jan	182	113	62.1	69	37.9	1:1.63	10.64	S**
Feb	182	126	69.2	56	30.8	1:2.22	26.92	S
Mar	302	183	60.6	119	39.4	1:1.56	13.56	S
Apr	168	93	55.4	75	44.6	1:1.22	1.93	NS
May	273	158	57.9	115	42.1	1:1.38	6.77	S
Jun	90	43	47.8	47	52.2	1:0.92	0.18	NS
Jul								
Aug	65	45	69.2	20	30.8	1:2.22	9.62	S
Sep	95	48	50.5	47	49.5	1:1.04	0.01	NS
Oct	294	155	52.7	139	47.3	1:1.13	0.87	NS
Nov	285	161	56.5	124	43.5	1:1.27	4.80	S
TOTAL	**2311**	**1326**	**57.4**	**985**	**42.6**	**1:1.32**	**50.32**	S

* Difference is not significant

** Difference is significant

Table 26: Monthwise sex ratio in nearshore waters

MONTHS	TOTAL PRAWNS	NO. OF FEMALES	% OF FEMALES	NO. OF MALES	% OF MALES	SEX RATIO	χ^2 VALUE	SIGNIFICANCE
Dec								
Jan								
Feb	125	77	61.6	48	38.4	1:1.63	6.73	S**
Mar	167	106	63.5	61	36.5	1:1.7	12.13	S
Apr	90	47	52.2	43	47.8	1:1.08	0.18	NS*
May	140	87	62.1	53	37.9	1:1.63	8.26	S
Jun								
Jul								
Aug	252	129	51.2	123	48.8	1:1.04	0.14	NS
Sep	95	52	54.7	43	45.3	1:1.22	0.85	NS
Oct	155	87	56.1	68	43.9	1:1.27	2.33	NS
Nov	76	46	60.5	30	39.5	1:1.56	3.37	NS
TOTAL	**1100**	**631**	**57.4**	**469**	**42.6**	**1:1.32**	**23.86**	S

* Difference is not significant

** Difference is significant

Table 27: Monthwise sex ratio in offshore waters

MONTHS	TOTAL PRAWNS	NO. OF FEMALES	% OF FEMALES	NO. OF MALES	% OF MALES	SEX RATIO	χ^2 VALUE	SIGNIFICANCE
Dec	360	265	73.6	95	26.4	1:2.84	80.28	s*
Jan	311	246	79.1	65	20.9	1:3.29	105.34	s
Feb	352	273	77.6	79	22.4	1:3.54	106.92	s
Mar	401	274	68.3	127	31.7	1:2.12	53.89	s
Apr	265	183	69.1	82	30.9	1:2.22	38.49	s
May	353	260	73.7	93	26.3	1:2.84	79.01	s
Jun	380	245	64.5	135	35.5	1:1.77	31.84	s
Jul	391	253	64.7	138	35.3	1:1.86	33.82	s
Aug	275	169	61.5	106	38.5	1:1.56	14.43	s
Sep	444	313	70.5	131	29.5	1:2.33	74.60	s
Oct	245	166	67.8	79	32.2	1:2.12	30.89	s
Nov	279	185	66.3	94	33.7	1:1.94	29.68	s
TOTAL	**4056**	**2832**	**69.8**	**1224**	**30.2**	**1:2.43**	**637.49**	**S**

* Difference is significant

Table 28: Monthwise sex ratio pooled for the three fishing zones

MONTHS	TOTAL PRAWNS	NO. OF FEMALES	% OF FEMALES	NO. OF MALES	% OF MALES	SEX RATIO	χ^2 VALUE	SIGNIFICANCE
Dec	735	466	63.4	269	36.6	1:1.7	52.80	**s***
Jan	493	359	72.8	134	27.2	1:2.7	102.69	**s**
Feb	659	476	72.2	183	27.8	1:2.6	130.27	**s**
Mar	870	563	64.7	307	35.3	1:1.86	75.33	**s**
Apr	523	323	61.8	200	38.2	1:1.63	28.93	**s**
May	766	505	65.9	261	34.1	1:1.94	77.72	**s**
Jun	470	288	61.3	182	38.7	1:1.56	23.91	**s**
Jul	391	253	64.7	138	35.3	1:1.86	33.82	**s**
Aug	592	343	57.9	249	42.1	1:1.38	14.93	**s**
Sep	634	413	65.1	221	34.9	1:1.86	58.15	**s**
Oct	694	408	58.8	286	41.2	1:1.44	21.45	**s**
Nov	640	392	61.3	248	38.8	1:1.56	32.40	**s**
TOTAL	**7467**	**4789**	**64.1**	**2678**	**35.9**	**1:1.94**	**596.80**	**s**

* Difference is significant

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Table 29: Sizewise sex ratio in shallow nearshore waters

SIZE CLASS	TOTAL PRAWNS	NO. OF FEMALES	% OF FEMALES	NO. OF MALES	% OF MALES	SEX RATIO	χ^2 VALUE	SIGNIFICANCE
61-65	1		0	1	100	1:0	1	NS*
66-70	9	7	77.8	2	22.2	1:3.54	2.78	NS
71-75	23	11	47.8	12	52.2	1:0.92	0.04	NS
76-80	28	15	53.6	13	46.4	1:1.17	0.14	NS
81-85	73	37	50.7	36	49.3	1:1.04	0.01	NS
86-90	96	44	45.8	52	54.2	1:0.85	0.67	NS
91-95	127	56	44.1	71	55.9	1:0.78	1.77	NS
96-100	137	57	41.6	80	58.4	1:0.72	3.86	S**
101-105	169	81	47.9	88	52.1	1:0.92	0.29	NS
106-110	162	74	45.7	88	54.3	1:0.85	1.21	NS
111-115	224	91	40.6	133	59.4	1:0.69	7.88	S
116-120	223	83	37.2	140	62.8	1:0.59	14.57	S
121-125	238	110	46.2	128	53.8	1:0.85	1.36	NS
126-130	206	108	52.4	98	47.6	1:1.08	0.49	NS
131-135	155	130	83.9	25	16.1	1:5.25	71.13	S
136-140	126	113	89.7	13	10.3	1:9	79.37	S
141-145	115	111	96.5	4	3.5	1:32	99.56	S
146-150	67	66	98.5	1	1.5	1:99	63.06	S
151-155	71	71	100					
156-160	25	25	100					
161-165	23	23	100					
166-170	11	11	100					
171-175	0							
176-180	0							
181-185	1	1	100					
186-190	1	1	100					
TOTAL	2311	1326	57.4	985	42.6	1:1.32	50.32	S

* Difference is not significant

** Difference is significant

Table 30: Sizewise sex ratio in nearshore waters

SIZE CLASS	TOTAL PRAWNS	NO. OF FEMALES	% OF FEMALES	NO. OF MALES	% OF MALES	SEX RATIO	χ^2 VALUE	SIGNIFICANCE
61-65								
66-70								
71-75	5	4	80.0	1	20.0	1:4	1.8	NS*
76-80	10	2	20.0	8	80.0	1:0.25	3.6	NS
81-85	31	16	51.6	15	48.4	1:1.08	0.032	NS
86-90	21	7	33.3	14	66.7	1:0.49	2.33	NS
91-95	41	20	48.8	21	51.2	1:0.96	0.02	NS
96-100	53	24	45.3	29	54.7	1:0.82	0.47	NS
101-105	65	34	52.3	31	47.7	1:1.08	0.14	NS
106-110	98	36	36.7	62	63.3	1:0.59	6.90	S**
111-115	111	41	36.9	70	63.1	1:0.59	7.58	S
116-120	128	56	43.8	72	56.3	1:0.78	2.00	NS
121-125	132	72	54.5	60	45.5	1:1.22	1.09	NS
126-130	100	48	48.0	52	52.0	1:0.92	0.16	NS
131-135	80	56	70.0	24	30.0	1:2.33	12.80	S
136-140	50	42	84.0	8	16.0	1:5.25	23.12	S
141-145	57	55	96.5	2	3.5	1:24	49.28	S
146-150	46	46	100					
151-155	40	40	100					
156-160	19	19	100					
161-165	10	10	100					
166-170	1	1	100					
171-175	0							
176-180	1	1	100					
181-185	1	1	100					
186-190								
TOTAL	1100	631	57.4	469	42.6	1:1.32	23.86	S

* Difference is not significant

** Difference is significant

Table 31: Sizewise sex ratio in offshore waters

SIZE CLASS	TOTAL PRAWNS	NO. OF FEMALES	% OF FEMALES	NO. OF MALES	% OF MALES	SEX RATIO	χ^2 VALUE	SIGNIFICANCE
61-65								
66-70								
71-75	4	1	25.0	3	75.0	1:0.33	1	NS*
76-80	16	8	50.0	8	50.0	1:1	0	NS
81-85	21	11	52.4	10	47.6	1:1.08	0.048	NS
86-90	42	22	52.4	20	47.6	1:1.08	0.095	NS
91-95	79	41	51.9	38	48.1	1:1.08	0.114	NS
96-100	140	72	51.4	68	48.6	1:1.04	0.114	NS
101-105	200	96	48.0	104	52.0	1:0.92	0.320	NS
106-110	222	97	43.7	125	56.3	1:0.78	3.532	NS
111-115	258	144	55.8	114	44.2	1:1.27	3.488	NS
116-120	348	164	47.1	180	51.7	1:0.9	0.744	NS
121-125	415	205	49.4	210	50.6	1:0.96	0.060	NS
126-130	443	259	58.5	184	41.5	1:1.38	12.698	S**
131-135	380	282	74.2	98	25.8	1:2.85	89.095	S
136-140	405	360	88.9	45	11.1	1:8.09	245.00	S
141-145	341	328	96.2	13	3.8	1:24	290.98	S
146-150	259	256	98.8	3	1.2	1:99	247.14	S
151-155	196	196	100				196.00	S
156-160	136	136	100				136.00	S
161-165	69	69	100				69.00	S
166-170	42	42	100				42.00	S
171-175	23	23	100				23.00	S
176-180	9	9	100				9.00	S
181-185	8	8	100				8.00	S
186-190	3	3	100				3.00	S
TOTAL	4059	2832	69.8	1223	30.1	1:2.33	638.44	S

Table 32: Sizewise sex ratio, pooled for the three fishing zones

SIZE CLASS	TOTAL PRAWNS	NO. OF FEMALES	% OF FEMALES	NO. OF MALES	% OF MALES	SEX RATIO	χ^2 VALUE	SIGNIFICANCE
61-65	1	0	0.0	1	100.0	1:0	1	NS*
66-70	9	7	77.8	2	22.2	1:3.54	2.78	NS
71-75	32	16	50.0	16	50.0	1:1	0.00	NS
76-80	54	25	46.3	29	53.7	1:0.85	0.30	NS
81-85	125	64	51.2	61	48.8	1:1.04	0.07	NS
86-90	159	73	45.9	86	54.1	1:0.85	1.06	NS
91-95	247	117	47.4	130	52.6	1:0.89	0.68	NS
96-100	330	153	46.4	177	53.6	1:0.85	1.75	NS
101-105	434	211	48.6	223	51.4	1:0.96	0.33	NS
106-110	482	207	42.9	275	57.1	1:0.57	9.59	S**
111-115	593	276	46.5	317	53.5	1:0.89	2.83	NS
116-120	695	303	43.6	392	56.4	1:0.78	11.40	S
121-125	785	387	49.3	398	50.7	1:0.96	0.15	NS
126-130	749	415	55.4	334	44.6	1:1.22	8.76	S
131-135	615	468	76.1	147	23.9	1:3.17	167.55	S
136-140	581	515	88.6	66	11.4	1:8.09	346.99	S
141-145	513	494	96.3	19	3.7	1:24	439.81	S
146-150	372	368	98.9	4	1.1	1:99	356.17	S
151-155	307	307	100					
156-160	180	180	100					
161-165	102	102	100					
166-170	54	54	100					
171-175	23	23	100					
176-180	10	10	100					
181-185	10	10	100					
186-190	4	4	100					
TOTAL	7466	4789	64.1	2677	35.9	1:1.77	597.45	S

4.8 Fecundity:

Fecundity is the number of mature ova liberated during the spawning season (or in a year) in the case of seasonally spawning and temperate water fishes. However, the tropical penaeid prawn spawn throughout the year therefore, the number of ova liberated at every spawning can be termed batch fecundity. Ovaries of 67 mature prawns ranging from 102 mm to 162 mm in total length were examined for fecundity studies. The details of total length, total weight, ovary weight and fecundity have been presented in Table 33.

The linear as well as exponential relationship of fecundity to total length, total weight and ovary weight was calculated using least square regression analysis. The results obtained are as follows (presented in Table 34):

Fecundity and total length

The linear relationship between fecundity and total length is described by the equation-

$$F = -56159 + 5726.933\,L \qquad (r = 0.79)$$

whereas the exponential relationship is described by the equation

$$F = 0.0002\,L^{4.9427} \qquad (r = 0.86)$$

From the correlation coefficients, we can infer that fecundity and total length show a good exponential relationship.

Fecundity and total weight

The linear relationship between fecundity and total weight is given by the equation-

$$F = -38030 + 013263\ W \qquad (r = 0.82)$$

and the exponential relationship is described by the equation-

$$F = 5860\ W^{1.202} \qquad (r = 0.85)$$

High correlation coefficient indicates exponential relationship between fecundity and total weight of the prawn.

Fecundity and ovary weight

Linear regression analysis between fecundity and ovary weight gave the following expression-

$$F = 49373 + 119911.50\ O.Wt \qquad (r = 0.89)$$

Exponential relationship between fecundity and ovary weight is expressed as-

$$F = 166500\ O.Wt.^{0.8311} \qquad (r = 0.90)$$

Very high value of correlation coefficient indicates that fecundity can best be related to ovary weight of the prawn and that the relationship is exponential.

Exponential relationships are graphically represented in Fig. 11, 12 and 13.

Table 33: Total length, total weight, ovary weight and fecundity of *M. affinis*

S. No.	TOTAL LENGTH (in mm)	TOTAL WEIGHT (in gm)	OVARY WEIGHT (in gm)	FECUNDITY
1	104.00	8.363	0.311	58261
2	102.00	7.319	0.474	58539
3	105.00	8.912	0.49	65741
4	109.00	8.283	0.342	66690
5	109.00	8.417	0.364	68675
6	108.00	9.318	0.454	76272
7	109.00	7.827	0.406	57043
8	111.00	9.061	0.56	123368
9	113.00	10.112	0.761	163234
10	119.00	12.338	0.729	178605
11	118.00	10.57	0.635	85045
12	120.00	11.116	0.844	130590
13	116.00	10.284	0.472	71744
14	116.00	10.158	0.45	81360
15	116.00	10.382	0.507	86922
16	116.00	11.507	0.446	60210
17	118.00	11.421	0.896	146445
18	121.00	11.758	0.413	101185
19	125.00	13.516	0.663	127959
20	124.00	13.54	1.198	120998
21	122.00	12.128	0.852	135255
22	128.00	12.461	0.453	114835
23	129.00	14.846	1.201	192520
24	130.00	17.169	1.466	219534
25	129.00	17.357	1.253	177675
26	128.00	15.759	1.024	143360
27	128.00	15.24	0.509	89838
28	126.00	15.449	1.064	124133
29	131.00	8.532	1.69	212602
30	132.00	16.995	0.723	121753
31	134.00	18.793	1.444	311248
32	135.00	18.632	1.055	110306
33	132.00	17.365	1.626	203250
34	132.00	15.123	0.633	143917
35	136.00	17.68	0.59	144550
36	140.00	18.104	1.388	199640
37	138.00	20.693	1.537	280759
38	140.00	22.38	1.343	336134
39	136.00	18.304	0.955	198958
40	136.00	19.74	1.286	312820

41	137.00	17.534	1.017	169898
42	138.00	20.871	0.894	202491
43	140.00	20.568	0.736	175703
44	140.00	18.104	1.13	241820
45	139.00	19.274	1.842	249945
46	142.00	19.245	2.017	242376
47	144.00	23.762	1.445	216028
48	141.00	19.766	1.945	259463
49	142.00	22.045	1.146	215906
50	150.00	26.27	3.284	487908
51	146.00	23.265	2.236	279093
52	148.00	25.643	1.934	194174
53	149.00	24.139	1.25	314821
54	148.00	24.408	2.556	267371
55	149.00	26.046	1.568	246848
56	147.00	25.17	2.325	285593
57	150.00	25.772	1.547	229730
58	147.00	24	1.714	205870
59	146.00	23.641	2.324	295148
60	151.00	27.895	3.174	475522
61	153.00	30.052	1.116	298181
62	153.00	30.459	4.664	568160
63	153.00	26.286	1.91	375697
64	156.00	27.444	1.383	251706
65	156.00	28.013	0.907	200719
66	156.00	27.229	1.011	241629
67	162.00	34.244	3.096	448146

Table 34: Relationship of fecundity with size and weight of prawn

RELATION		EQUATION	COEFFICIENT OF CORRELATION 'r'
Fecundity - Total Length	Linear	$F = -56159 + 5726.93\ L$	0.79
	Exponential	$F = 0.0002\ L^{4.2497}$	0.86
Fecundity - Total Weight	Linear	$F = -38030 + 13263\ W$	0.82
	Exponential	$F = 5860\ W^{1.202}$	0.85
Fecundity - Ovary Weight	Linear	$F = 49373 + 119911\ O.\ Wt$	0.89
	Exponential	$F = 166500\ O.\ Wt^{0.8311}$	0.9

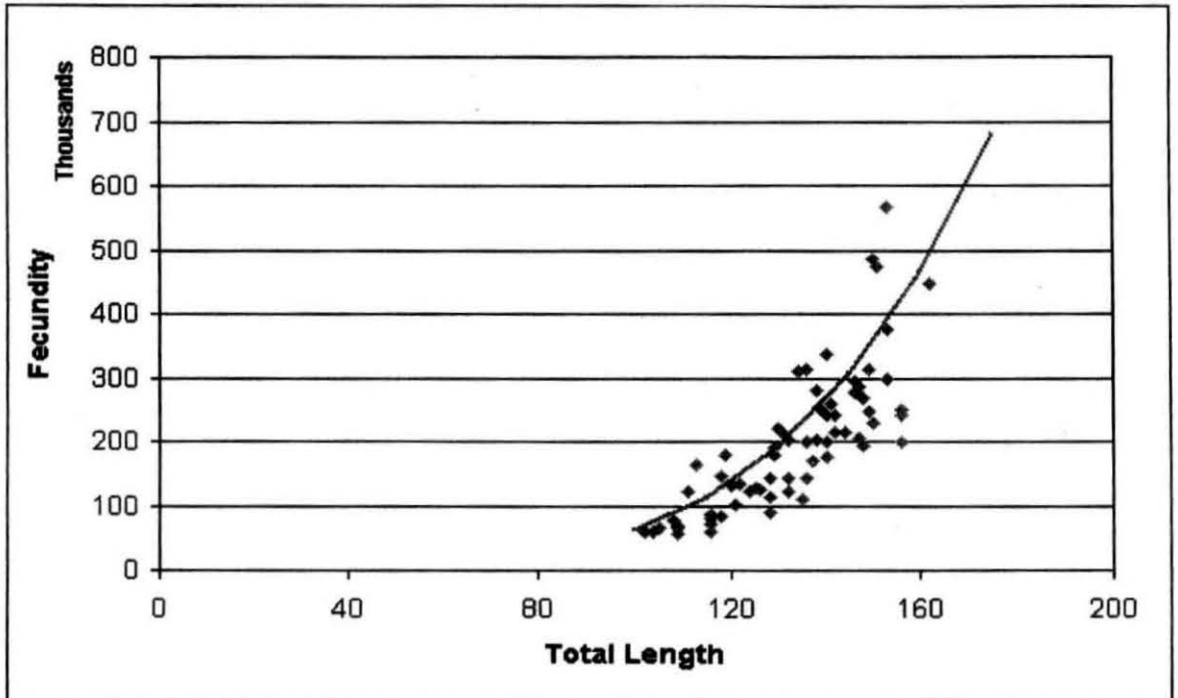

Fig. 11: Relation between fecundity and total length

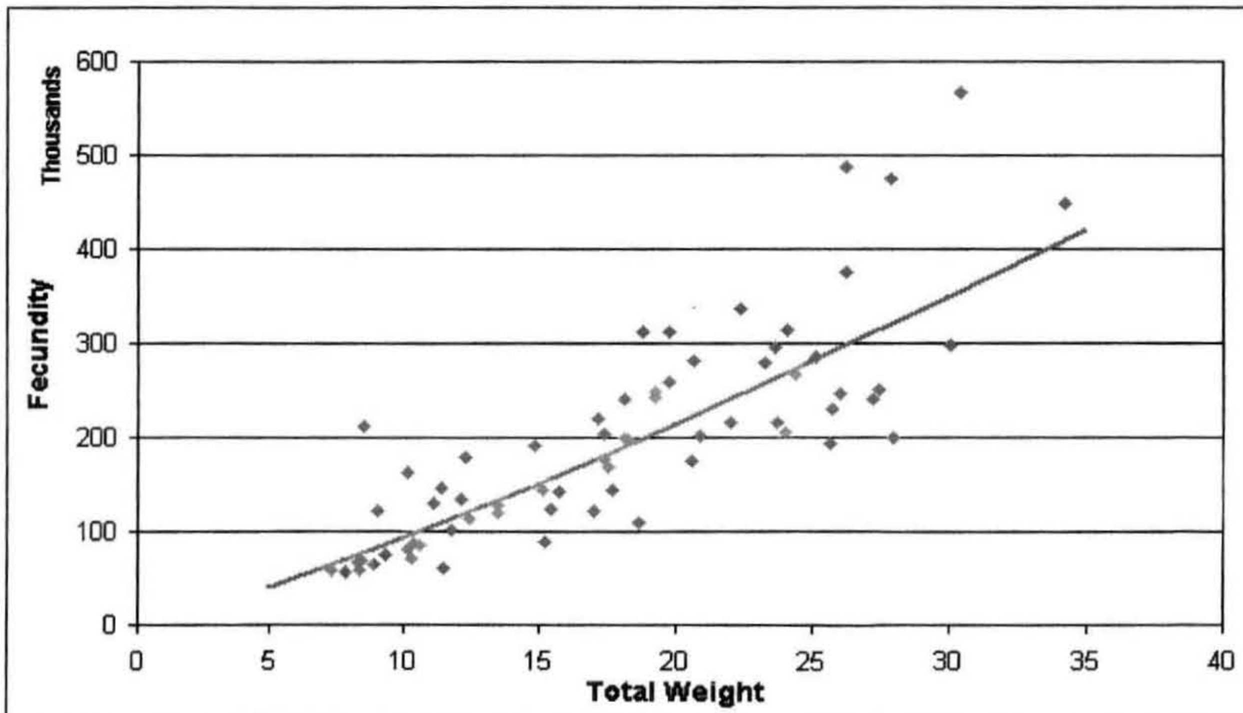

Fig. 12: Relation between fecundity and total weight

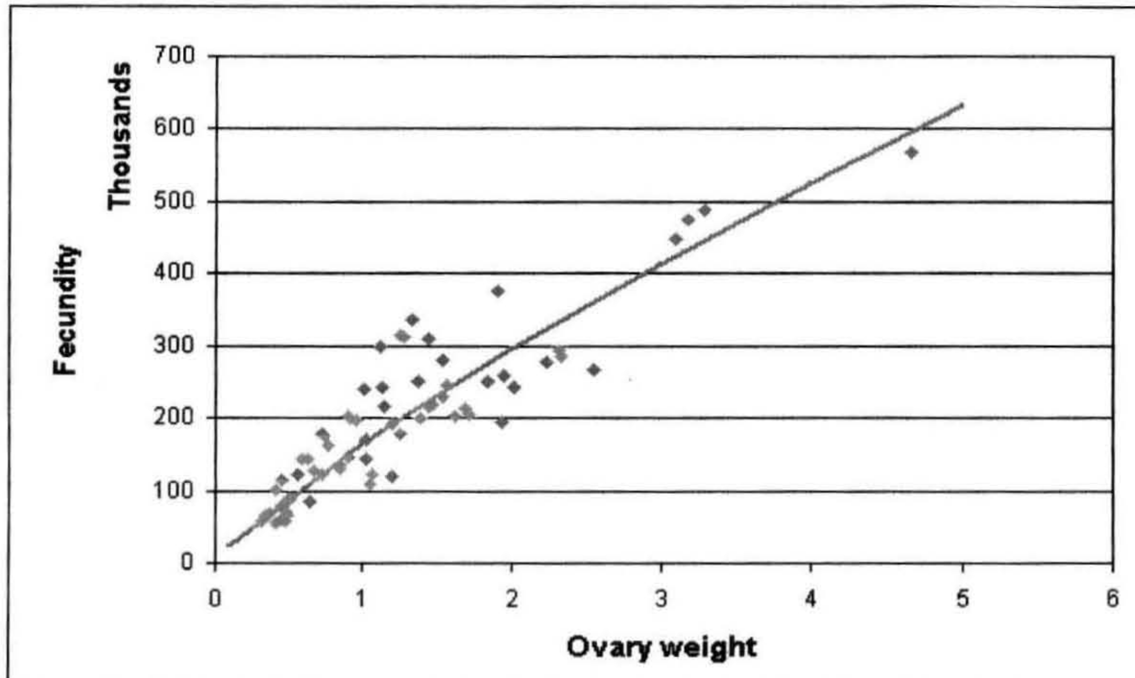

Fig. 13: Relation between fecundity and ovary weight

4.9 Population Fecundity Index:

Monthwise details of population fecundity estimation in offshore waters in December 1999 is presented in Table 35 and monthwise fecundity indices for the three fishing zones are presented in Table 36. In offshore waters, maximum egg production was seen in the month of September ($72 * 10^{12}$), followed by December ($69 * 10^{12}$) and minimum in May ($4.38 * 10^{12}$). No conclusions were drawn in case of nearshore waters due to inadequacy of data. In case of shallow nearshore waters, maximum egg production was in October ($0.89 * 10^{12}$), followed by November ($0.79 * 10^{12}$), and minimum in February and April.

Monthwise abundance of females, percentage of spawners and population fecundity indices in shallow nearshore waters, offshore waters and pooled for the three fishing zones is presented in Fig. 14, 15 and 16 respectively. Population fecundity index was observed to follow the same trend as the abundance of females rather than the proportion of spawners.

Table 35: Details of population fecundity index in offshore waters in Dec. 1999

SIZE CLASS	TOTAL F	ADULT F	PROP ADULT (Scl)	MATURE F	PROP MATURE (Pcl)	FECUNDITY(F)	Scl*Pcl*F
63						7370	0
68						10196	0
73						13679	0
78	80065	0	0		0	18268	0
83	272676	0	0		0	23788	0
88	206296	0	0		0	30502	0
93	160137	160137	1		0	38576	0
98	772332	772332	1	63115	0.082	48192	3938
103	533562	533562	1	49424	0.093	59529	5514
108	937554	937554	1	92037	0.098	72829	7149
113	1142043	1142043	1	531842	0.466	88274	41109
118	1753720	1753720	1	1061753	0.605	106106	64240
123	1143756	1143756	1	755095	0.660	126571	83561
128	1008708	1008708	1	473713	0.470	149926	70409
133	1210205	1210205	1	588152	0.486	176441	85749
138	1655121	1655121	1	925446	0.559	206401	115407
143	612986	612986	1	374602	0.611	240104	146730
148	942514	942514	1	473713	0.503	277863	139656
153	1375347	1375347	1	1312244	0.954	320002	305320
158	588046	588046	1	390307	0.664	366863	243500
163	192573	192573	1	192573	1	418798	418798
168	49424	49424	1	49424	1	476177	476177
173	126230	126230	1	126230	1	539382	539382
178	49424	49424	1	49424	1	608811	608811
183	189345	189345	1	189345	1	684875	684875
188	63115	63115	1	63115	1	768002	768002
TOTAL	15065179	14506142		7761554			4808327

Table 36: Monthwise population fecundity index in the three fishing zones

ZONE / MONTH	OFFSHORE	NEARSHORE	SHALLOW NEARSHORE
Dec. 1999	$69.75 * 10^{12}$		$0.29 * 10^{12}$
Jan. 2000	$14.32 * 10^{12}$		$0.20 * 10^{12}$
Feb. 2000	$4.96 * 10^{12}$	$6.33 * 10^{12}$	$0.11 * 10^{12}$
Mar. 2000	$9.99 * 10^{12}$	$1.68 * 10^{12}$	$0.29 * 10^{12}$
Apr. 2000	$6.32 * 10^{12}$	$1.46 * 10^{12}$	$0.11 * 10^{12}$
May 2000	$4.38 * 10^{12}$	$2.3 * 10^{12}$	$0.43 * 10^{12}$
Jun. 2000	$6.42 * 10^{12}$		$0.12 * 10^{12}$
Jul. 2000	$5.59 * 10^{12}$		
Aug. 2000	$7.28 * 10^{12}$	$1.16 * 10^{12}$	$0.11 * 10^{12}$
Sep. 2000	$72.72 * 10^{12}$	$6.35 * 10^{12}$	$0.58 * 10^{12}$
Oct. 2000	$16.15 * 10^{12}$	$9.23 * 10^{12}$	$0.89 * 10^{12}$
Nov. 2000	$7.75 * 10^{12}$	$4.38 * 10^{12}$	$0.79 * 10^{12}$

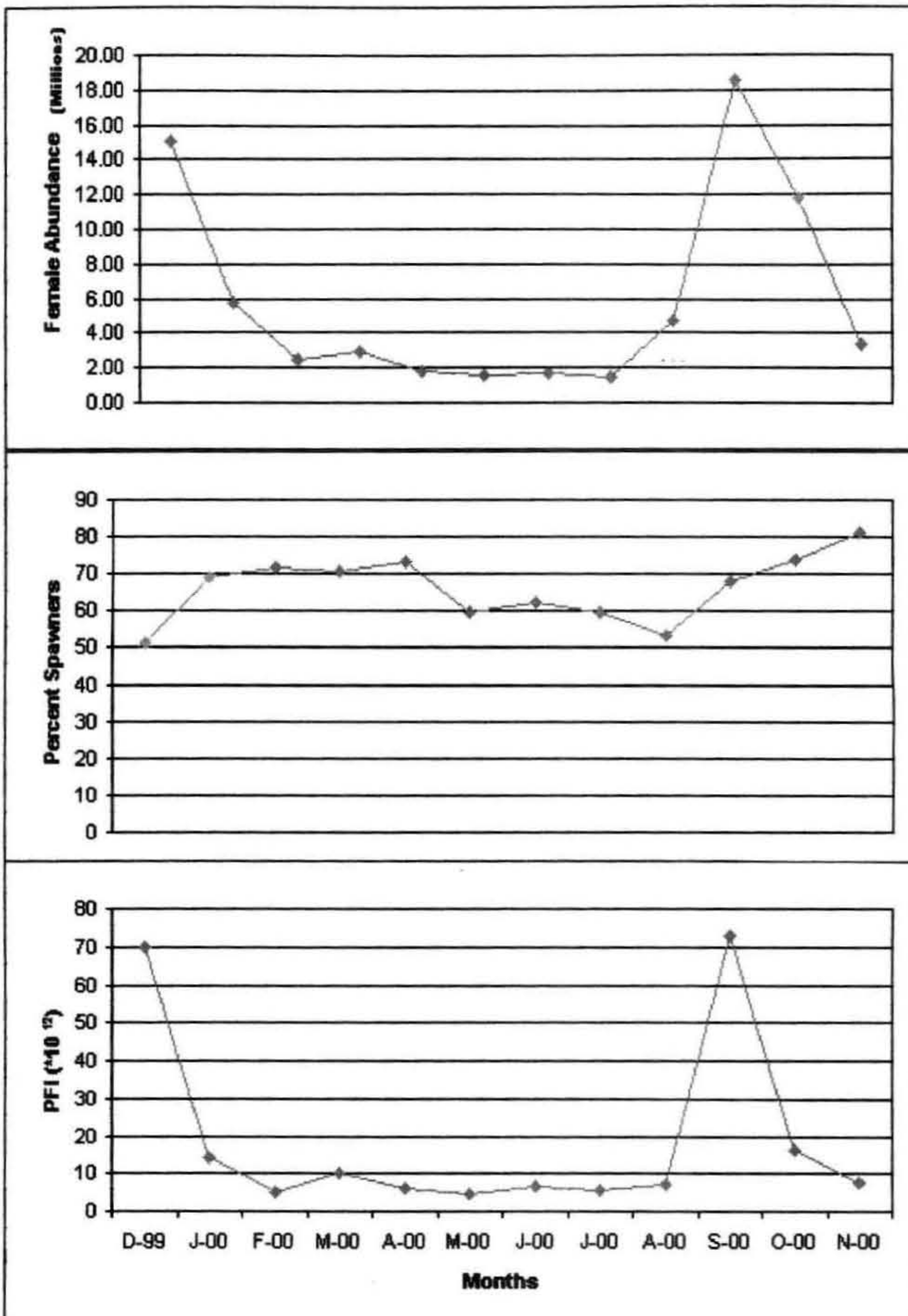

Fig 14: Monthwise abundance of females, percentage of spawners and population fecundity index in offshore waters.

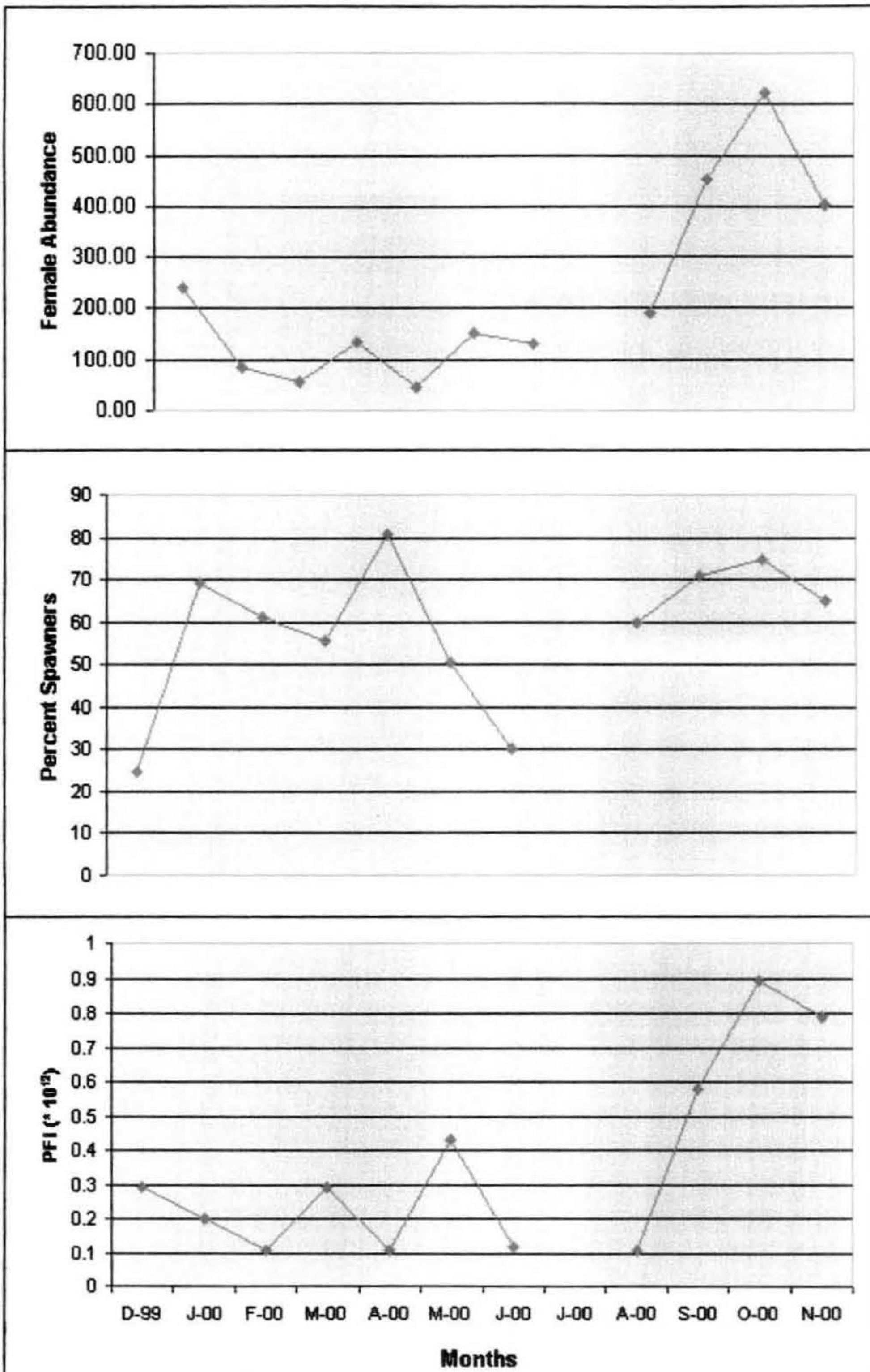

Fig 15: Monthwise abundance of females, percentage of spawners and population fecundity index in shallow nearshore waters.

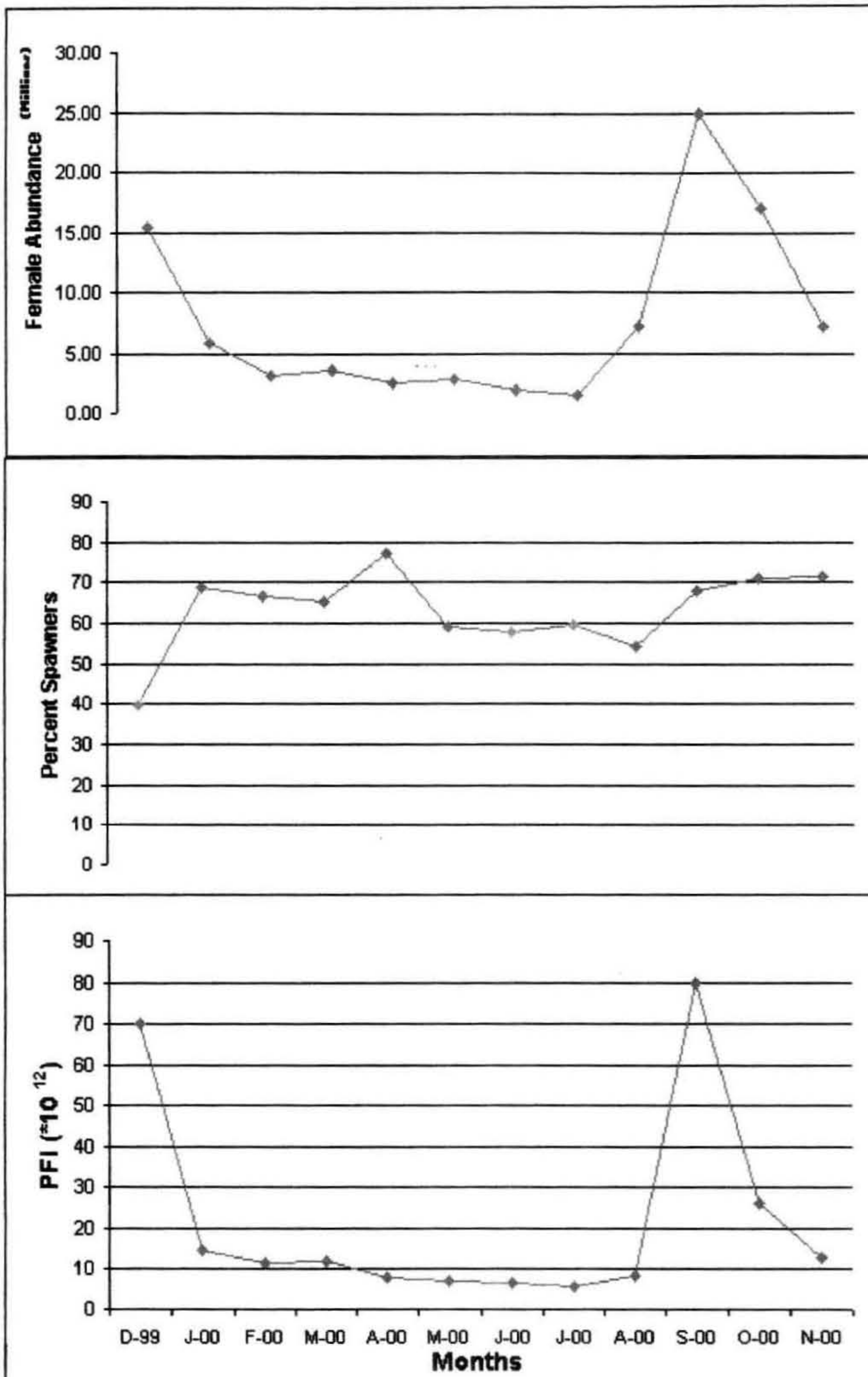

Fig 16: Monthwise abundance of females, percentage of spawners and population fecundity index pooled for the three fishing zones.

4.10 Age and Growth:

A total number of 2,687 males in the size range of 65 - 150 mm and 4,913 females in the size range of 66 - 190 mm were examined from shallow nearshore, nearshore and offshore water for the growth studies. Since all the methods adopted in the present investigation are based on length frequency data, month wise length frequencies were pooled for the three different fishing zones.

4.10.1 modal progression analysis

Fig. 17 and Fig. 18 show progression of modes of important modal sizes in males and females respectively.

In case of males, mode 'a1' at 120.2 mm in December 1999 has moved to 'a2' at 129.46 mm in February 2000 showing a growth of 9.26 mm in two months. Mode 'b1' at 109.2 mm in December has moved to 'b2' at 116.37 mm in January, recording a growth of 7.17 mm in a month. Mode 'c1' at 104.98 mm in March increased by 15.85 mm in two months, moving to 'c2' at 120.85 mm in May. Mode 'd1' at 106.19 mm in April moved to 'd2' at 115.66 mm in June, showing a growth of 9.47 mm in two months. Mode 'e1' at 99.72 mm in June has moved to 'e2' at 109.06 mm in July and to 'e3' at 121.01 mm in September showing an increase of 9.34 mm in the first month and 11.95 mm in the next two months.

Similarly in case of females, mode 'a1' at 100.87 mm in December 1999 moved to 'a2' at 129.47 mm in January 2000 and to 'a3' at 146.29 mm in Feb. 2000, showing a growth of 28.6 mm in the first month and 16.82 mm in the second month. Mode 'b1' at 175 mm in January has moved to 'b2' 180 mm showing a growth of 5 mm in a month. Mode 'c1' at

85 mm in February has moved to 'c2' at 103.87 mm in March and the growth recorded is 18.87 mm in a month. Mode 'd1' *from 90.29 mm in* March has moved to 'd2' at 106.85 mm in April showing a growth of 16.65 mm in a month. Mode 'e1' at 104.8 mm in July has moved to 'e2' at 123.64 mm in August, recording a growth of 18.64 mm Mode 'f1' at 105.95 mm in August has moved to 'f2' at 123.99 mm in September – a growth of 18.04 mm. In case of smaller size group, mode 'g1' at 75.08 mm in September has moved to 'g2' at 104.7 mm in October, which is a growth of 29.62 mm and mode 'h1' at 85.26 mm in October has moved to 'h2' at 109.87 mm in November, showing a growth of 24.61 mm.

Progressions of modal lengths, from initial to final sizes, their increments and the growth rates per month are given in Table 37 for males and Table 38 for females.

By using Gulland and Holt plot (Gulland and Holt, 1959) growth parameters obtained were:

Males	L_∞ = 155.14 mm	K = 1.94	(r = 0.72)
Females	L_∞ = 210.8 mm	K = 2.47	(r = 0.34)

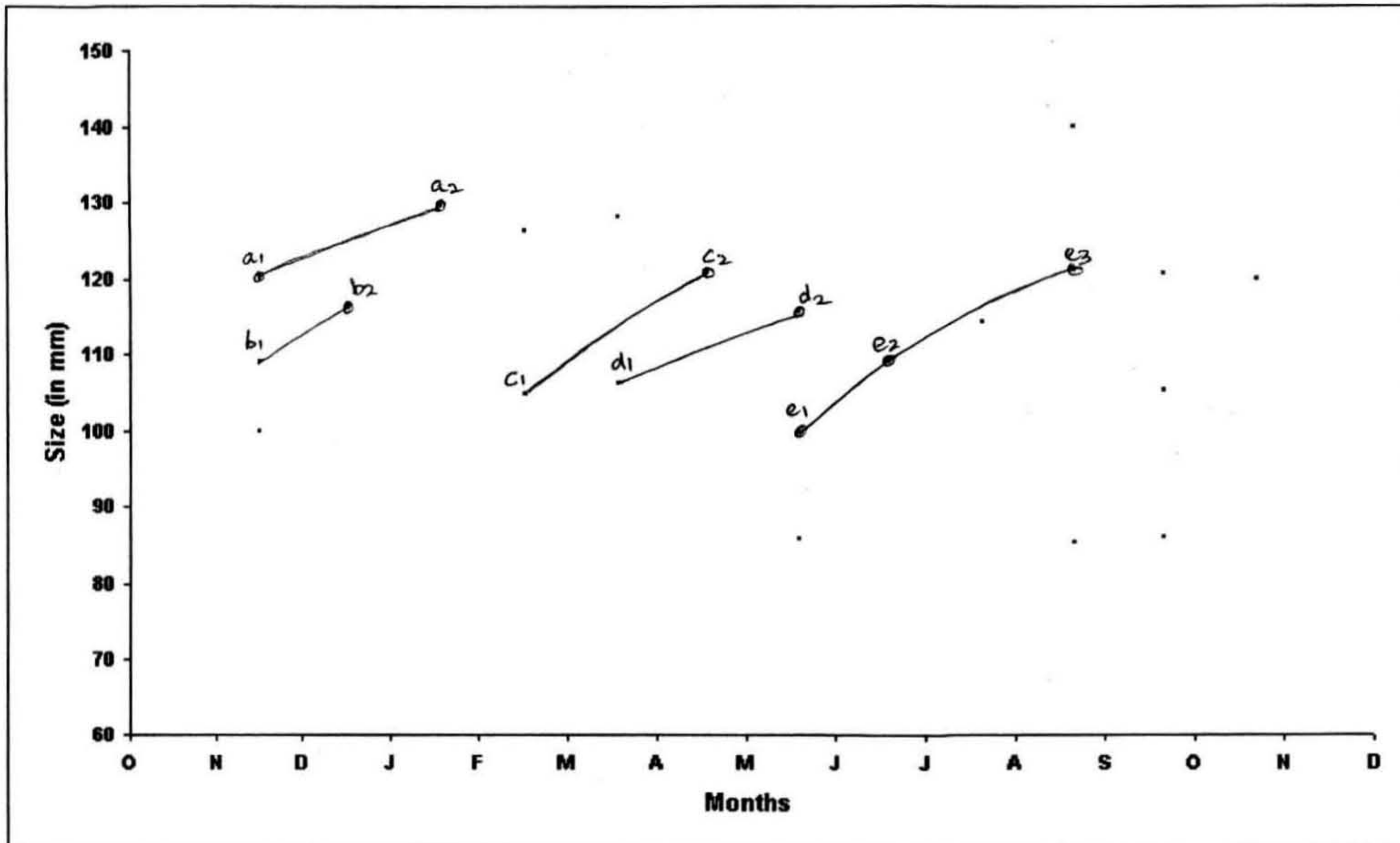

Fig 17: Progression of modes in males

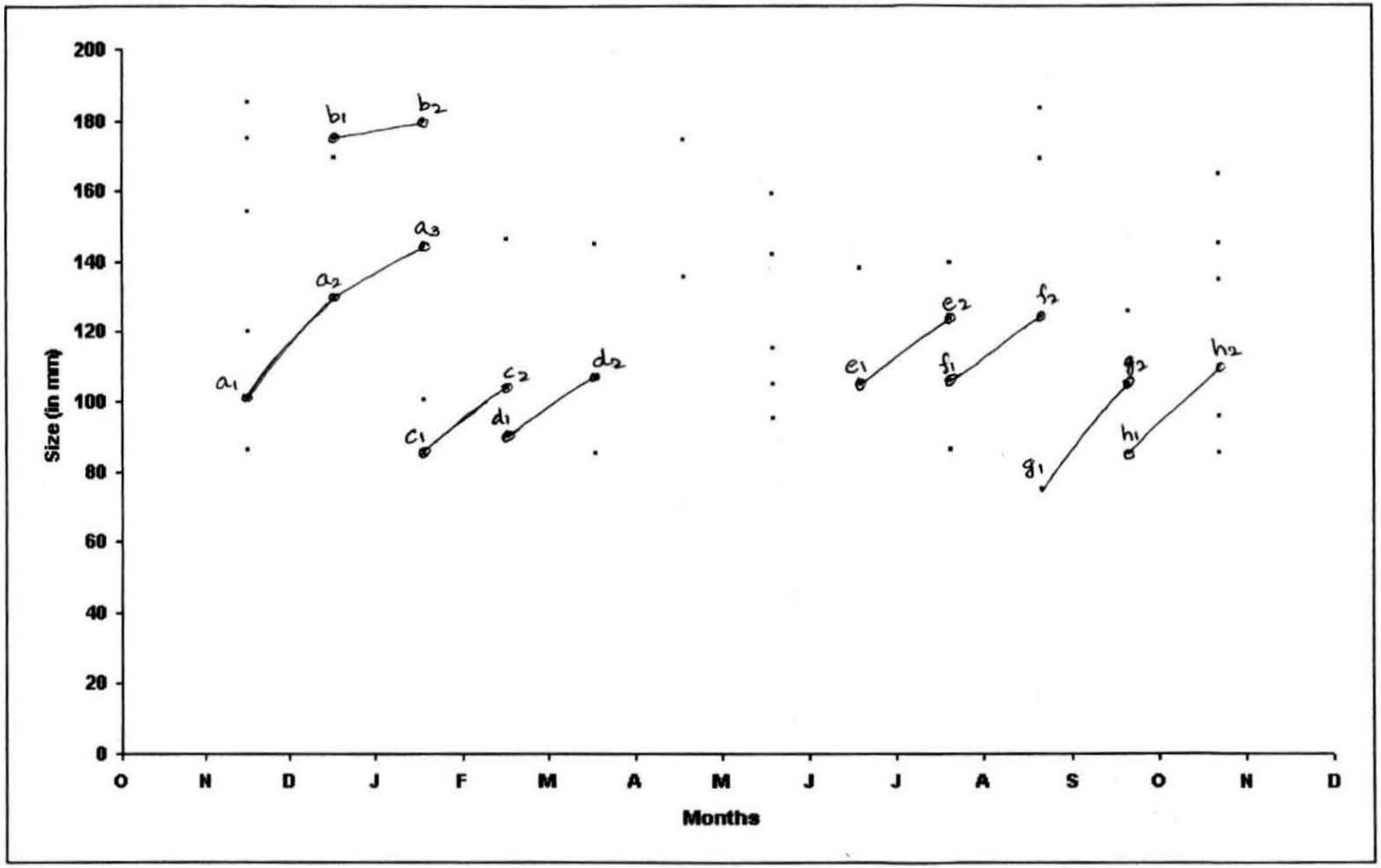

Fig 18: Progression of modes in females

Table 37: Progression of modes in males

S. No	L1 (in mm)	L2 (in mm)	Change in length	Change in time	ΔL/ΔT	Mean length
1	120.2	129.49	9.29	2	4.645	124.85
2	109.2	116.37	7.17	1	7.17	112.79
3	104.98	120.85	15.87	2	7.935	112.92
4	106.19	115.66	9.47	2	4.735	110.93
5	99.72	109.06	9.34	1	9.34	104.39
6	109.06	114.24	5.18	1	5.18	115.04
7	114.24	121.01	6.77	1	6.77	117.63
POOLED	-	-	**63.09**	**10**	**6.309**	

Table 38: Progression of modes in females

S. No	L1 (in mm)	L2 (in mm)	Change in length	Change in time	ΔL/ΔT	Mean length
1	100.87	129.47	28.6	1	28.6	115.17
2	129.47	146.29	16.82	1	16.82	137.88
3	175	180	5	1	2.5	177.5
4	85	103.87	18.87	1	9.435	94.435
5	90.29	106.85	16.56	1	5.52	98.57
6	104.8	123.64	18.84	1	18.84	114.22
7	105.95	123.99	18.04	1	18.04	114.97
8	75.08	104.7	29.62	1	14.81	89.89
9	85.26	109.87	24.61	1	24.61	97.565
POOLED	-	-	**176.96**	**9**	**12.64**	

4.10.2 ELEFAN I method

Fig. 19 shows the restructured length frequency showing peaks and troughs together with growth curve and the maximum Rn value estimated for the males of *M. affinis*. The growth parameters obtained are L_∞ = 160 mm, K = 2 with Rn value 0.164, starting sample being 9 and starting length 78 mm. This method does not estimate t_0, so, it is taken as 0, as suggested by Pauly and David (1981).

Fig. 20 shows the restructured length frequency for females. Starting sample taken is 4 and starting length 88 mm. The growth parameters obtained are L_∞ 198.38 mm, K 2.5 with Rn value 0.134.

4.10.3 Powell – Wetherall plot

The growth curves and growth parameter estimates obtained by this method for males and females are shown in Fig. 21 and Fig. 22 respectively. In this method, instead of K, Z/K is obtained, where Z is the total mortality coefficient.

The values of L_∞ and Z/K obtained were:

Males: L_∞ = 157.62 mm, Z/K = 4.806

Females: L_∞= 198.38 mm, Z/K = 2.472

4.10.4 von Bertalanffy plot

Growth curves and growth parameter estimates, together with their standard errors (s.e.) obtained by seasonalised and non seasonalised

growth programme, by plotting length against age, is shown in Figs. 23 and 24 for males and Figs. 25 and 26 for females. *This method, in* addition to L_∞ and K, also gives t_0.

The values obtained by seasonalised and non-seasonalised growth patterns were:

Male:

Seasonalised	Non-seasonalised
$L_\infty = 204.58 \pm 575.1$	$L_\infty = 160.04 \pm 3.69$
$K = 1.08 \pm 6.43$	$K = 2.37 \pm 0.19$
$t_0 = -0.19 \pm 1.12$	$t_0 = 0.009 \pm 0.018$
$C = 0.28 \pm 1.04$	
$WP = 0.87 \pm 0.69$	

Female:

Seasonalised	Non-seasonalised
$L_\infty = 239.9 \pm 253.7$	$L_\infty = 195.27 \pm 7.17$
$K = 1.26 \pm 2.69$	$K = 2.14 \pm 0.21$
$t_0 = -0.038 \pm 0.17$	$t_0 = 0.013 \pm 0.015$
$C = 0.91 \pm 0.57$	
$WP = 0.78 \pm 0.2$	

Values obtained by seasonalised growth in these cases cannot be accepted, as the standard error for both L_∞ and K are far greater than their means.

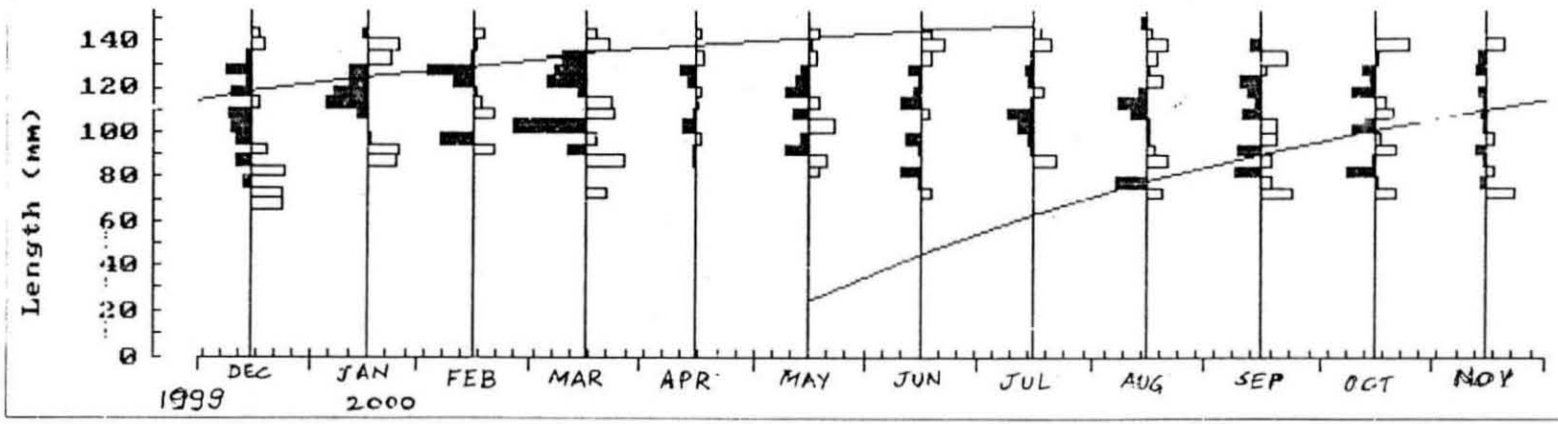

Fig. 19. Restructured length frequency by ELEFAN method in males

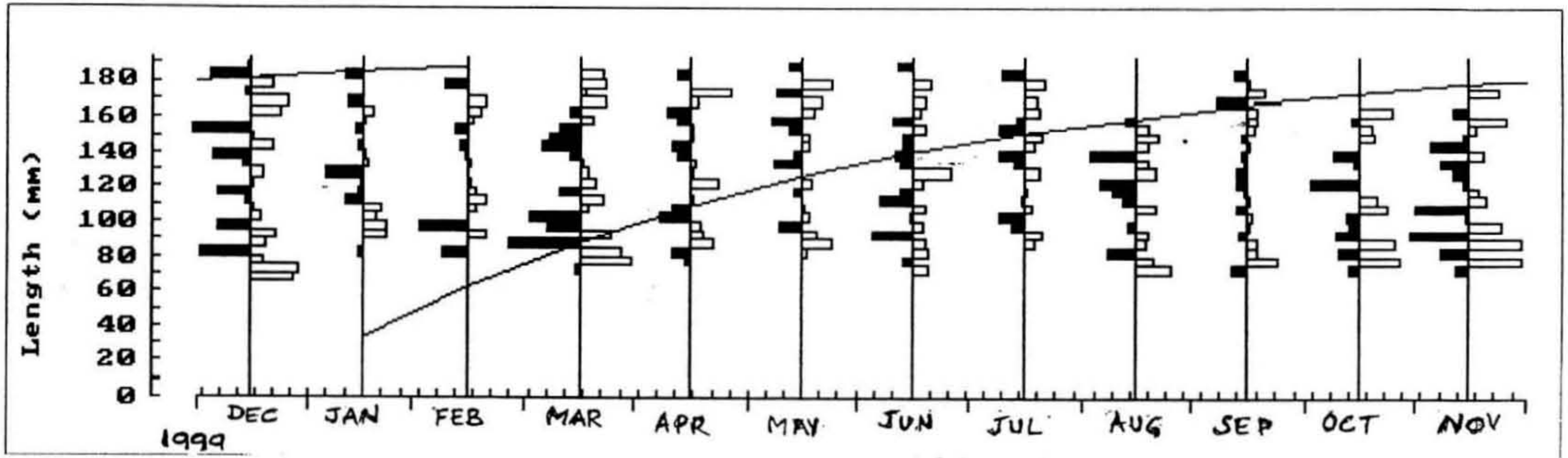

Fig. 20. Restructured length frequency by ELEFAN method in females

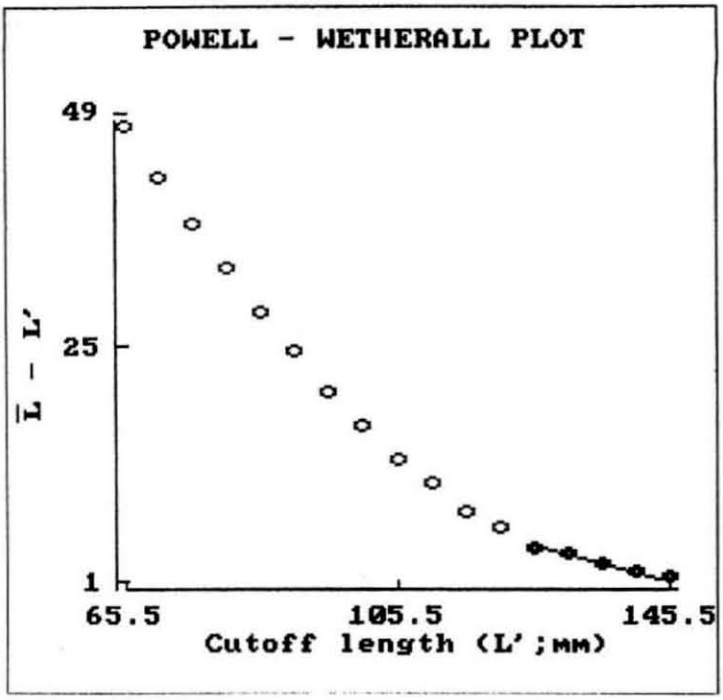

Fig. 21. Growth curve obtained by Powell-Wetherall plot in males

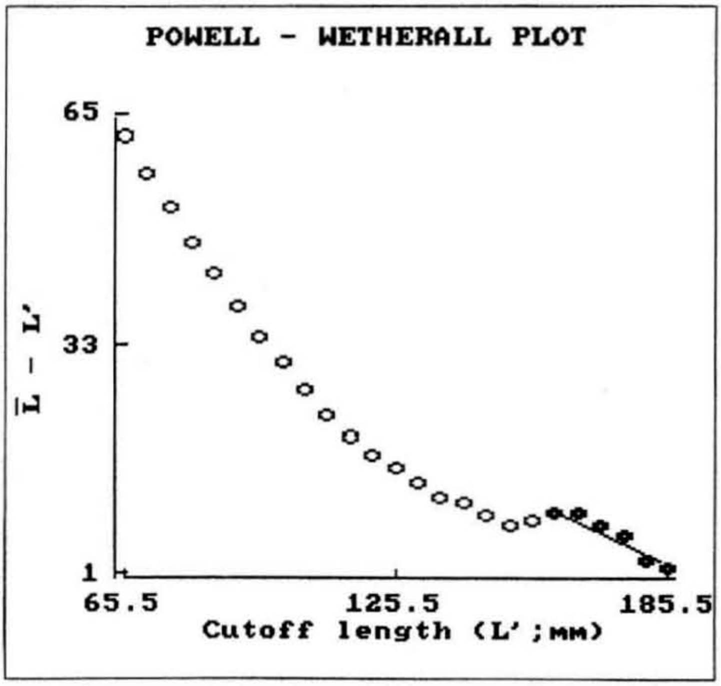

Fig. 22. Growth curve obtained by Powell-Wetherall plot in females

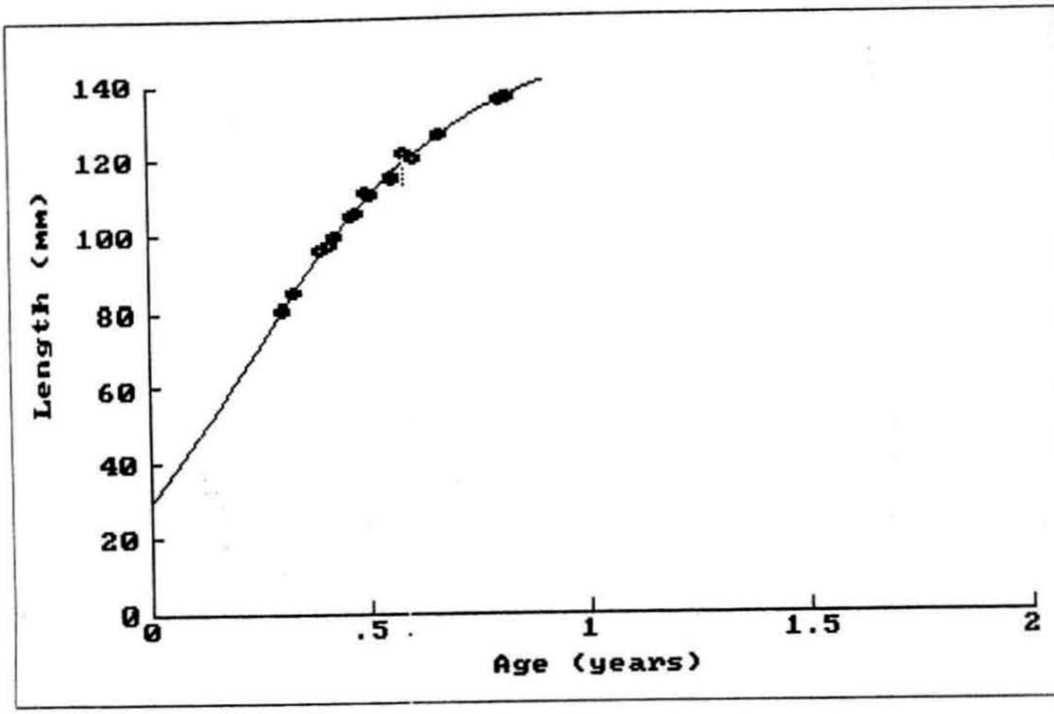

Fig. 23. Growth curve obtained by seasonalised von Bertalanffy plot in males

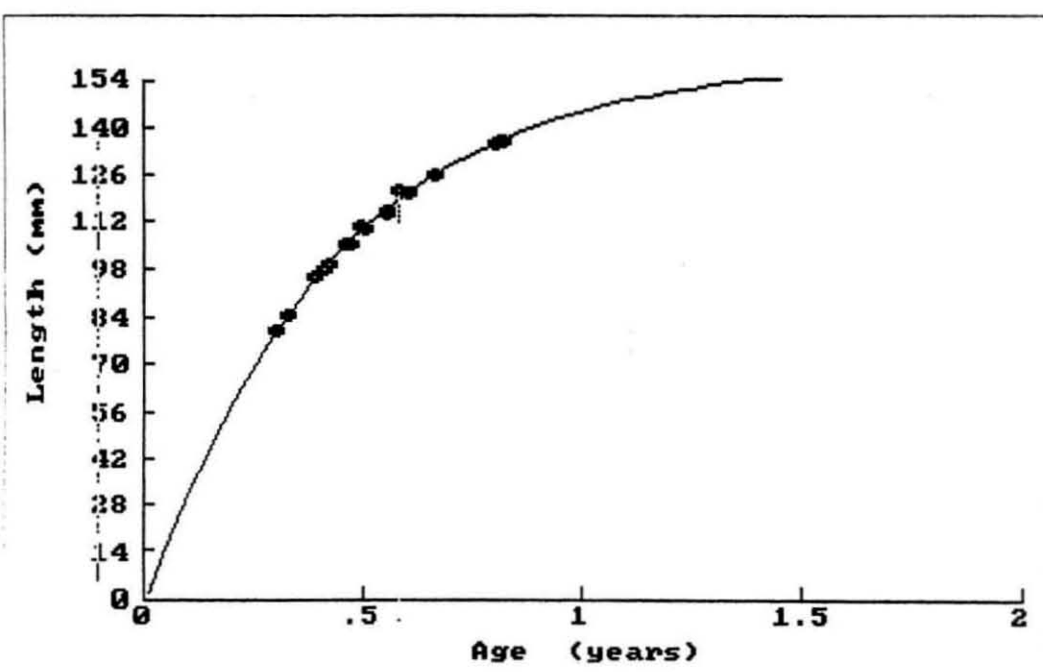

Fig. 24 Growth curve obtained by non-seasonalised von Bertalanffy plot in males

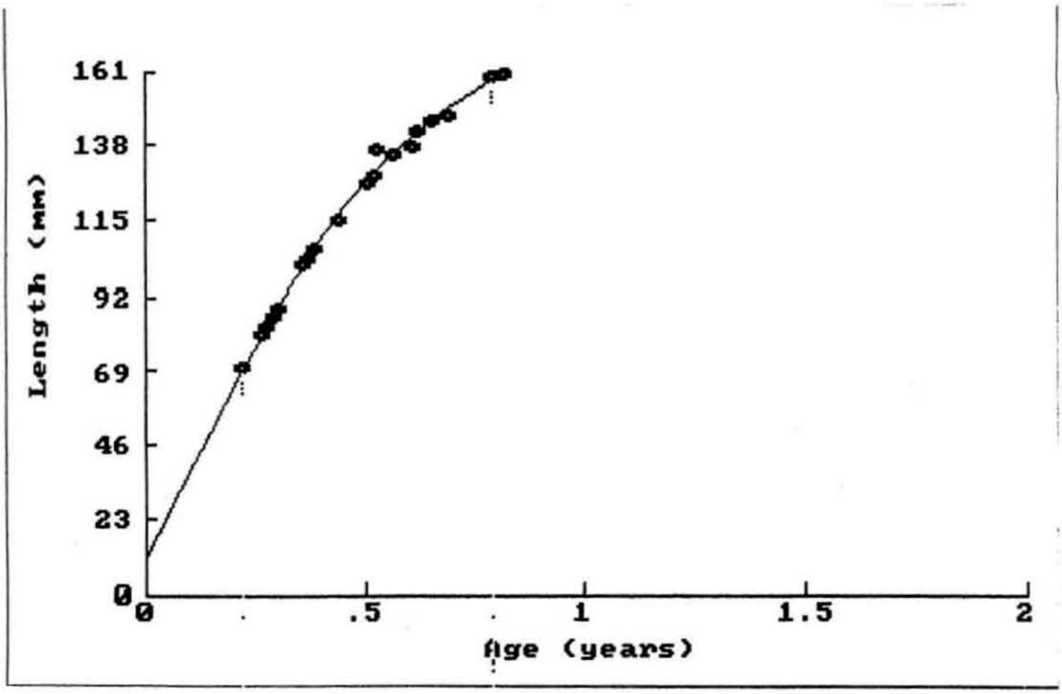

Fig. 25 Growth curve obtained by seasonalised von Bertalanffy plot in females

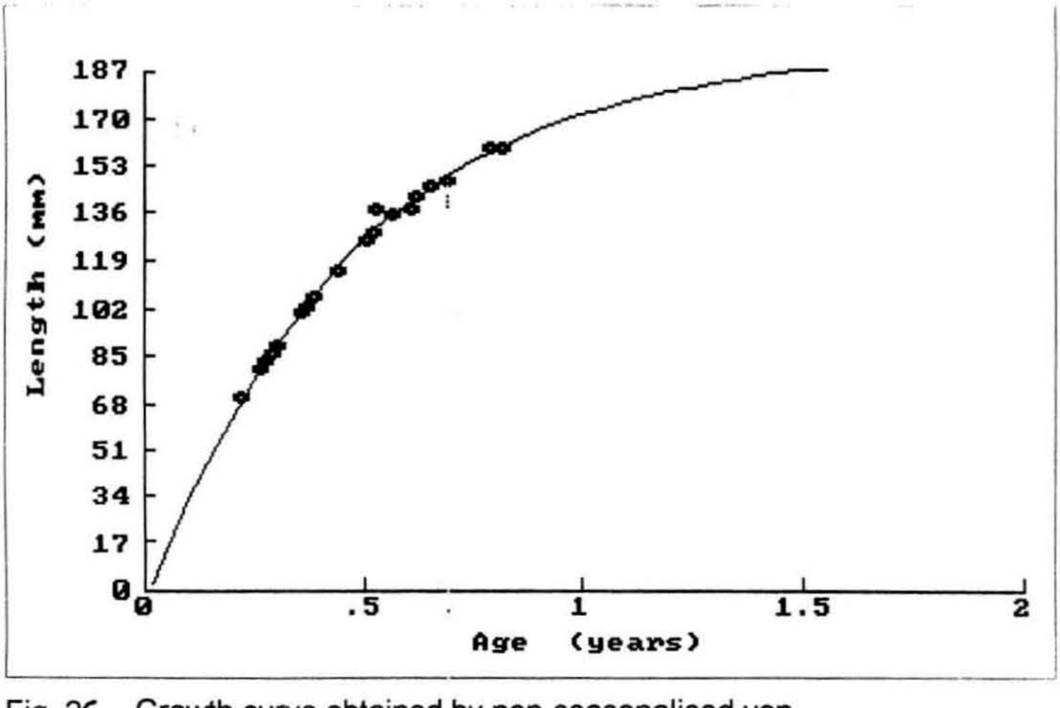

Fig. 26. Growth curve obtained by non-seasonalised von Bertalanffy plot in females

4.10.5 Bhattacharya method:

Monthwise length frequency distributions of the two sexes resolved by the programme into normal distributions along with their means and standard deviations are presented in Table 39 for males and Table 40 for females.

In the FiSAT computer programme, the monthwise mean sizes obtained by Bhattacharya method are plotted. These sizes are connected to get the appropriate growth curves. Linking of mean sizes for males and females are shown in Fig. 27 and Fig. 28 respectively.

4.10.5a Gulland and Holt plot

The growth increments per unit time calculated using progression of growth curves, have been employed to get the Gulland and Holt plot. By taking mean size ($\bar{L}$) on abscissa and growth increment per unit time ($\Delta L/\Delta t$) on ordinate, the Gulland and Holt plot are obtained and shown in Fig. 29 and Fig. 30 for males and females respectively.

For males the estimates were

L_∞ = 162.03 mm, K = 2.25 with regression coefficient r = 0.88

For females the estimates were

L_∞ = 204.55 mm, K = 1.91 with regression coefficient r = 0.83

4.10.5b Faben's method

The growth curves obtained by this method for males and females are shown in Fig. 31 and Fig. 32 respectively.

The growth parameters were

Males: $L_\infty = 160.69 \pm 6.45$,
$K = 2.33 \pm 0.32$

Females: $L_\infty = 200.03 \pm 8.89$,
$K = 2.06 \pm 0.26$

4.10.5c Appeldoorn's method

The growth curves and estimates of parameters for males and females are given in Fig. 33 and Fig. 34 respectively. In addition to standard errors of the estimates, this method also gives seasonality parameters such as wintering point (WP) and seasonality constant (C). The values obtained were

Males: $L_\infty = 160.66 \pm 6.91$
$K = 2.34 \pm 0.34$,
$WP = 0.635 \pm 0.0$
$C = 0.0 \pm 0.071$

Females: $L_\infty = 197.03 \pm 8.16$
$K = 2.11 \pm 0.25$,
$WP = 0.29 \pm 0.12$
$C = 0.103 \pm 0.062$

Growth parameters obtained by various methods in the present study are given in Table 41 and 42. It was observed that the values obtained by von Bertalanffy plot following seasonalised growth patterns were not in accordance with the values obtained by the other methods and the standard errors of all the estimates were very high. Therefore, these values were not taken into consideration. It was also ascertained that the values obtained by Gulland and Holt plot lay in the range of values obtained by Faben's and Appeldoorn's methods in 95% confidence limit. Therefore, for all practical purposes, values obtained by Gulland and Holt plot were used for calculating age and growth of the species.

Table 39: Monthwise mean sizes and standard deviations in males by Bhattacharya's method

Obs.	Date	Mean	s.d.
1	15-12-99	78.72	2.23
2	15-12-99	105.05	6.45
3	15-12-99	115.5	8.7
4	15-12-99	136.39	2.25
5	15-1-00	115.58	6.24
6	15-1-00	125.5	2.89
7	15-1-00	141.71	1.51
8	15-2-00	103.83	3.52
9	15-2-00	124.84	5.26
10	15-2-00	136.11	1.87
11	15-3-00	80.5	4.43
12	15-3-00	101.8	2.13
13	15-3-00	125.56	6.23
14	15-3-00	140.5	5.95
15	15-4-00	95.52	7.13
16	15-4-00	123.95	6.85
17	15-4-00	135.5	5.38
18	15-5-00	96.44	4.74
19	15-5-00	105.48	7.53
20	15-5-00	120.44	1.27
21	15-5-00	125.5	5.94
22	15-5-00	140.24	1.24
23	15-6-00	84.62	7.09
24	15-6-00	99.51	5.12
25	15-6-00	114.58	4.26
26	15-6-00	125.26	5.89
27	15-7-00	97.55	4.72
28	15-7-00	108.15	5.02
29	15-7-00	124.29	6.9
30	15-8-00	81.08	4.15
31	15-8-00	111.11	6.32
32	15-8-00	124.83	5.67
33	15-9-00	83.93	3.97
34	15-9-00	110.25	4.34
35	15-9-00	121.23	5.39
36	15-9-00	139.55	2
37	15-10-00	86.05	6.49
38	15-10-00	103.83	4.08
39	15-10-00	119.23	4.4
40	15-10-00	126.19	4.68
41	15-11-00	80.86	2.69
42	15-11-00	93.98	6.04
43	15-11-00	118	7.22
44	15-11-00	131.16	3.74
45	15-12-00	115.05	8.09
46	15-12-00	129.57	2.87

Table 40: Monthwise mean sizes and standard deviations in females by Bhattacharya's method

Obs.	Date	Mean	s.d.
1	15-12-99	84.68	4.19
2	15-12-99	99.62	3.54
3	15-12-99	117.95	5.45
4	15-12-99	135.25	5.73
5	15-12-99	152.25	6.44
6	15-12-99	180.97	4.85
7	15-1-00	122.73	6.95
8	15-1-00	144.33	10.34
9	15-1-00	170.5	3.06
10	15-2-00	103.3	2.96
11	15-2-00	128.19	3.34
12	15-2-00	145.72	5.43
13	15-2-00	156.72	2.76
14	15-3-00	88.94	2.58
15	15-3-00	101.45	6.53
16	15-3-00	120.19	3.74
17	15-3-00	143.97	9.16
18	15-3-00	159.17	4.37
19	15-3-00	175.1	3.54
20	15-4-00	83	4.25
21	15-4-00	106.56	6.3
22	15-4-00	141.91	8.67
23	15-4-00	159.97	4.82
24	15-5-00	101.19	6.08
25	15-5-00	120.08	8.6
26	15-5-00	136.94	6.78
27	15-5-00	155.21	5.6
28	15-5-00	172.17	2.79
29	15-6-00	80.84	4.84
30	15-6-00	93.9	3.47
31	15-6-00	115.09	6.23
32	15-6-00	144	5.49
33	15-6-00	162.71	8.09
34	15-6-00	170.5	7.52
35	15-7-00	102.61	5.56
36	15-7-00	120.93	5.87
37	15-7-00	135.63	7.89
38	15-7-00	156.63	3.73
39	15-8-00	86.22	6.03
40	15-8-00	104.41	6.64
41	15-8-00	119.12	6
42	15-8-00	137.33	3.86
43	15-9-00	70.5	3.11
44	15-9-00	102.37	8.69
45	15-9-00	126.4	10.55
46	15-9-00	147.22	5.31

47	15-9-00	166.67	3.58
48	15-10-00	70.5	3.36
49	15-10-00	80.48	4.61
50	15-10-00	101.95	2.27
51	15-10-00	123.65	4.41
52	15-10-00	136.63	5.75
53	15-10-00	155.58	3.48
54	15-11-00	70.5	2.97
55	15-11-00	80.5	3.16
56	15-11-00	95.2	1.17
57	15-11-00	107.76	4.19
58	15-11-00	128.86	8.38
59	15-11-00	140.88	7.81
60	15-11-00	165.5	3.4
61	15-12-00	93	3.58
62	15-12-00	115.73	7.4
63	15-12-00	135.89	10.98

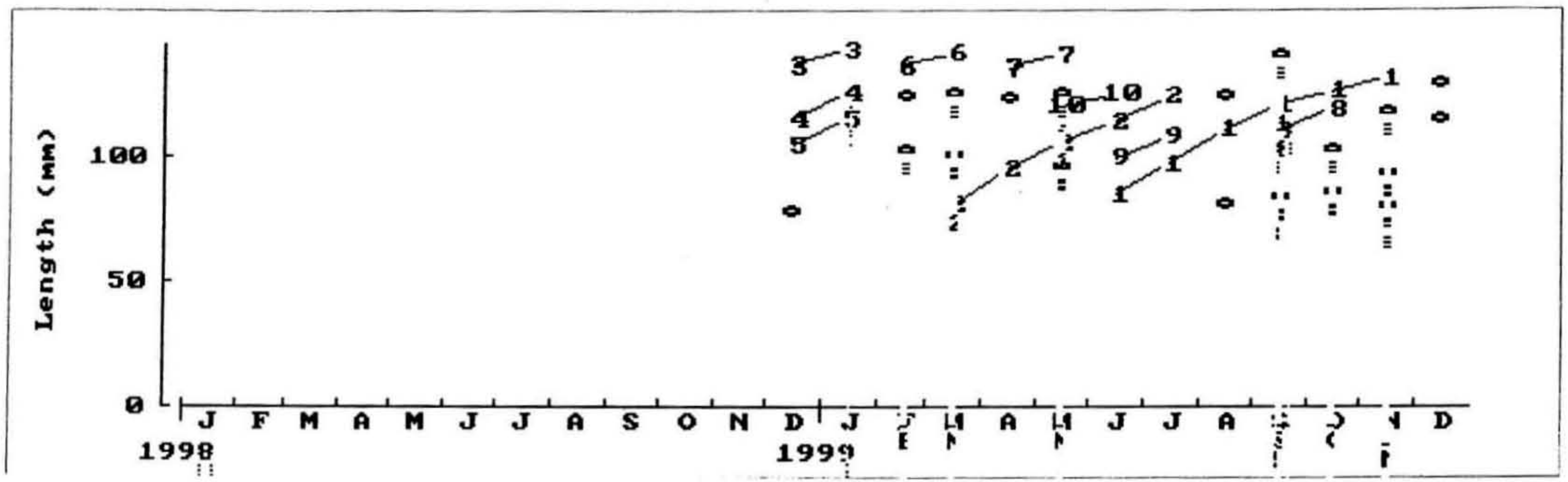

Fig. 27. Linking of means obtained by Bhattacharya method in males

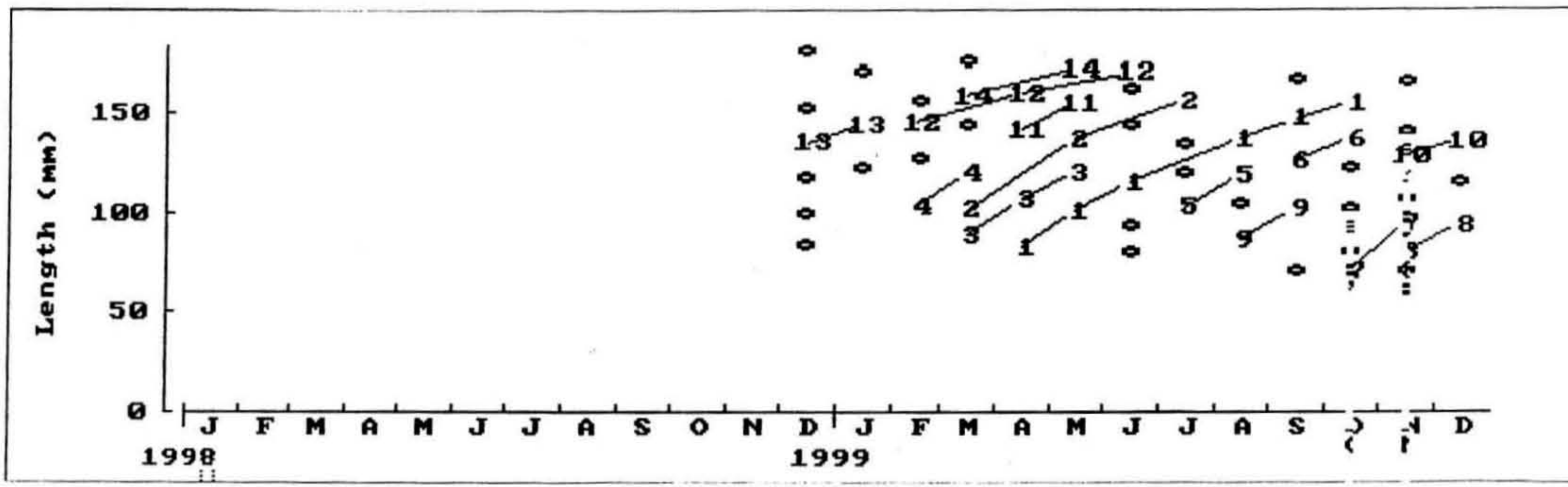

Fig. 28. Linking of means obtained by Bhattacharya method in females

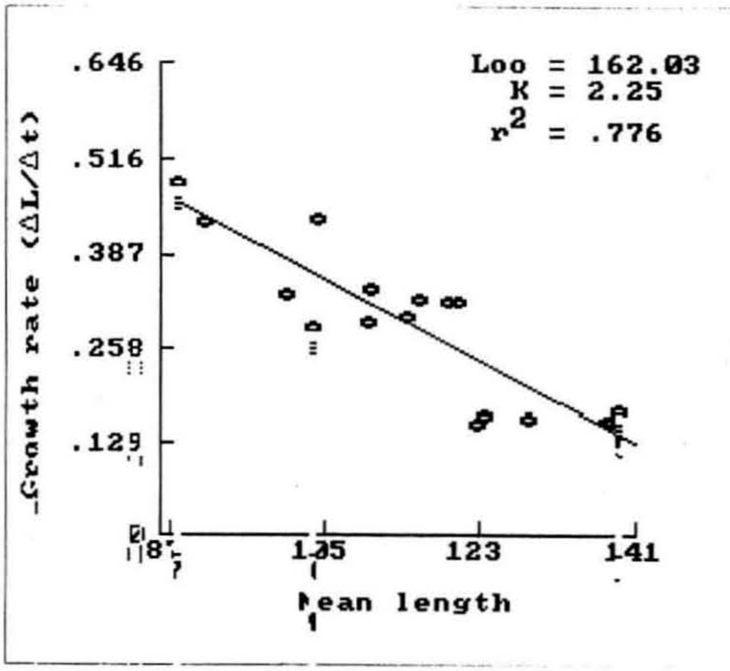

Fig. 29. Growth curve obtained by Gulland and Holt plot in males

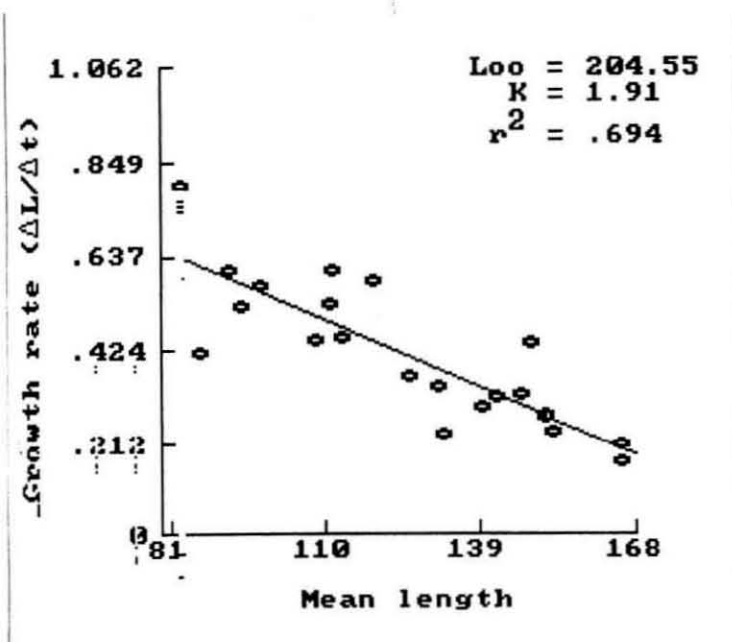

Fig. 30. Growth curve obtained by Gulland and Holt plot in females

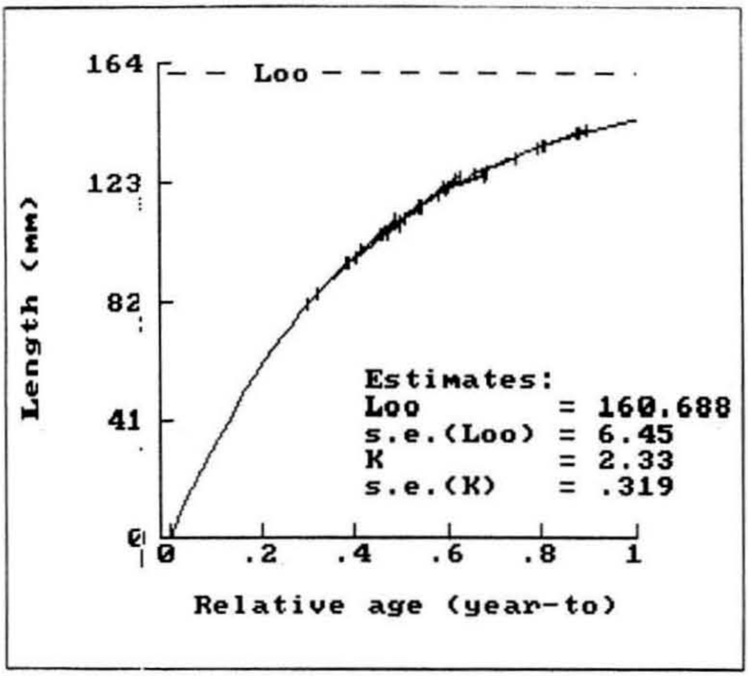

Fig. 31. Growth curve obtained by Faben's method in males

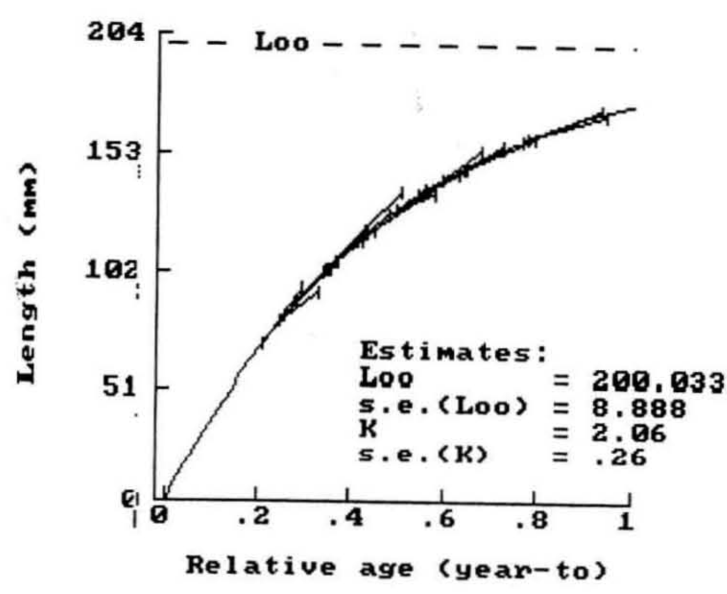

Fig. 32. Growth curve obtained by Faben's method in females

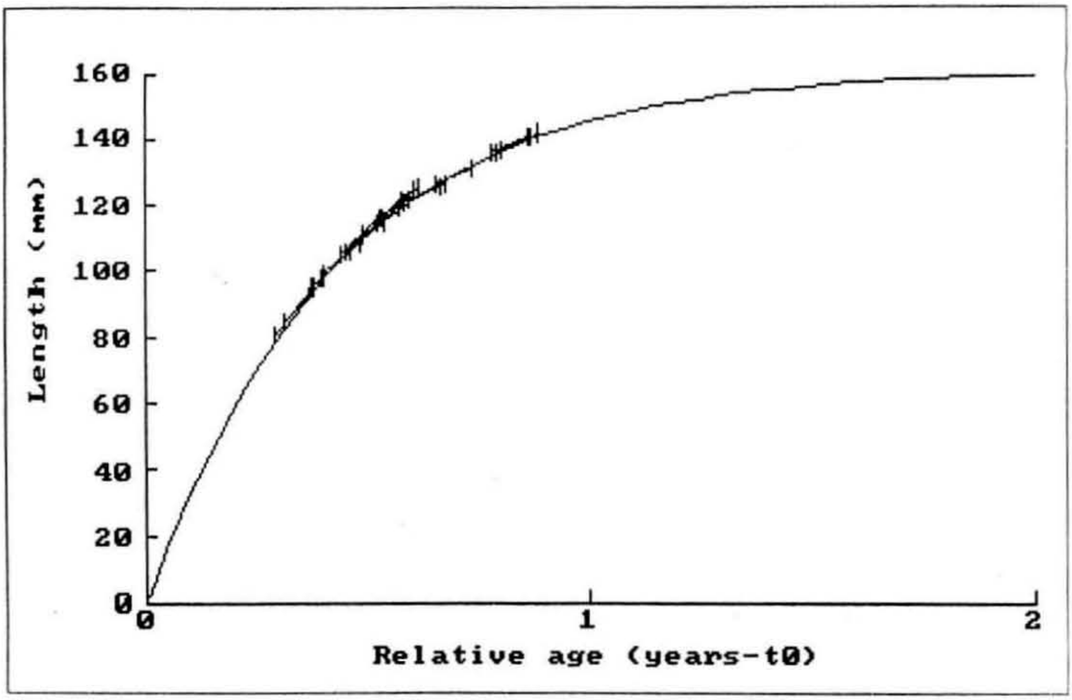

Fig. 33. Growth curve obtained by Appeldoorn's method in males

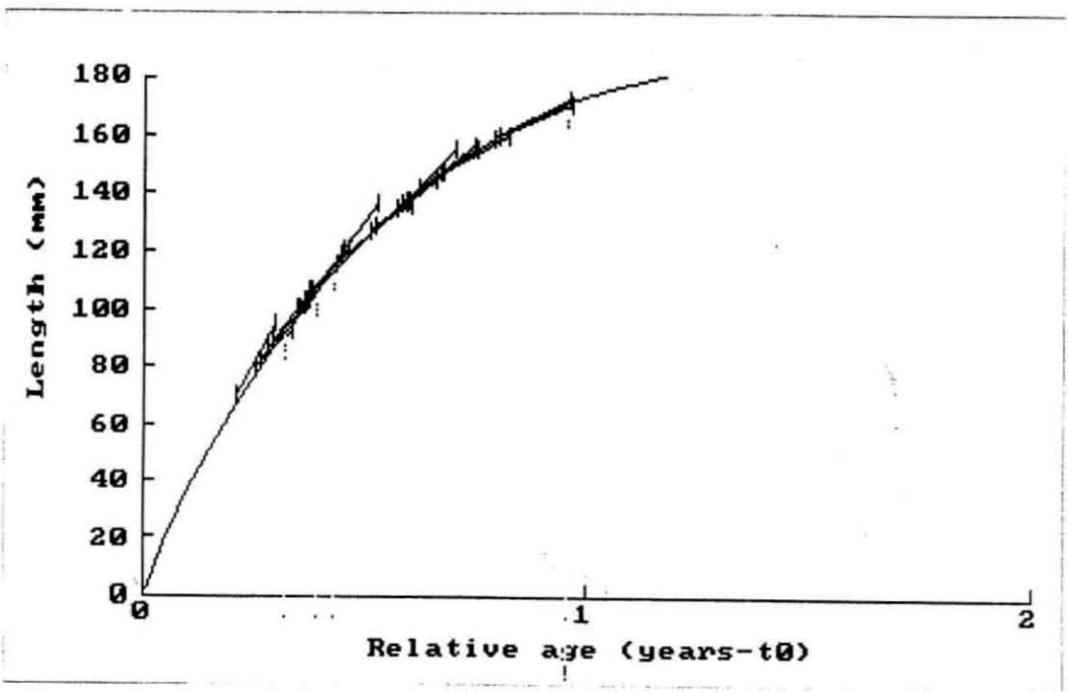

Fig. 34. Growth curve obtained by Appeldoorn's method in females

Table 41: Growth parameters of male obtained by various methods

Method	L_∞	K	to	C	WP	r	Rn
Modal Progression method	155.14	1.94				0.7	
Gulland & Holt Plot	162.03	2.25				0.88	
Faben's Method	160.69±6.45	2.33±0.32					
Powell-Wetherall Method	157.62	Z/K = 4.81					
Appeldoorn's Method	160.66±6.91	2.34±0.34		0	0.64		
ELEFAN 1 Method	160	2					0.164
Length at Age:							
Non seasonalised	160.04±3.67	2.37±0.19	0.009				
Seasonalised	204.59±575	1.09±6.43	-0.19				

Table 42: Growth parameters of female obtained by various methods

Method	L_∞	K	to	C	WP	r	Rn
Modal Progression method	210.8	2.47				0.76	
Gulland & Holt Plot	204.55	1.91				0.83	
Faben's Method	200.03±8.89	2.06±0.26					
Powell-Wetherall Method	198.38	Z/K = 2.472					
Appeldoorn's Method	197.03±8.16	2.11±0.25		0.1	0.29		
ELEFAN 1 Method	198.38	2.5					0.134
von Bertalanffy plot:							
Non seasonalised	195.27±7.17	2.14±0.21	0.013				
Seasonalised	239.96±253	1.26±2.69	-0.04				

4.10.6 growth performance index

In order to calculate φ, W_∞ was calculated as (W_∞= 27.18 g for males and 65.18g for females) by using their respective Length-Weight relationships (Section 4.2).

Growth performance index of males and females of *M. affinis* were estimated as

Male φ = 1.3081, φ' = 2.7712

Female φ = 1.4918, φ' = 2.9024

By using the growth parameters estimated by Gulland and Holt plot, the monthwise lengths estimated for males and females are given in Table 43.

Using the growth parameters estimated, males were 70.38 mm, 110.19 mm, 132 mm, 145.43 mm and 152.63 mm at the end of three, six, nine, twelve and fifteen months respectively. The same in the case of females was 77.95 mm, 126.2 mm, 156.05 mm, 174.52 mm, 185.95 mm and 193.02 mm at the end of three, six, nine, twelve, fifteen and eighteen months. Age of the largest male (150 mm) observed during the investigation was 1.16 years and that of the largest female (190 mm) was 1.4 years.

Table 43: Monthwise lengths attained by males and females of *M. affinis*

Age in Months	Size in mm	
	Male	**Female**
1	28	30
2	51	56
3	70	77
4	85	96
5	99	112
6	109	125
7	118	137
8	126	147
9	132	155
10	138	163
11	142	169
12	145	174
13	148	179
14	150	183
15	152	186

4.11 Mortality:

To estimate annual mortality coefficients of *M.affinis*, length frequency data was used as input, and growth parameters obtained by Gulland and Holt plot were considered. These were:

Male: $L_\infty = 162$ mm
$K = 2.25$
$t_0 = 0$

Female: $L_\infty = 204$ mm
$K = 1.91$
$t_0 = 0$

Total Mortality

4.11.1 Length-converted catch curve method:

Total mortality estimates obtained by length-converted catch curve method are presented in Fig. 35 for males and Fig. 36 for females. The estimates were:

Male: 13.06 $year^{-1}$
Female: 7.18 $year^{-1}$

Natural Mortality

Since direct estimation of natural mortality is not possible, three different methods were employed to estimate it.

4.11.2 Alagaraja's (1984) method:

Largest male prawn found during the period of investigation was 150 mm in length and the largest female was 190 mm in length. Their corresponding ages calculated by inverse VBGF were 1.25 years for males and 1.4 years for females. Natural mortality was estimated by using these as longevity and the estimates were:

Males: 3.8 $year^{-1}$
Female: 3.29 $year^{-1}$

4.11.3 Pauly's (1980a) method:

In order to use Pauly's empirical formula, the average annual surface temperature of 28.2^{0}C was considered from the average of bimonthly temperature reported by Bapat *et al*, (1982). Natural mortality, M, was estimated as:

Males: 3.62 $year^{-1}$
Females: 3.05 $year^{-1}$

4.11.4 Rikhter and Efanov's (1976) method:

The size at 50% maturity in males is 87 mm and in females it is 114 mm and the corresponding age calculated by inverse VBGF is 0.34 years and 0.43 years for the two sexes respectively. Natural mortalities estimated by Rikhter and Efanov's (1976) method were:

Male: 3.15 $year^{-1}$
Female: 2.64 $year^{-1}$

Natural mortality estimated for the two sexes by various methods is presented in Table 44.

It seen that the estimates obtained by Alagaraja's method (1984) are on the higher side while those by Rikhter and Efanov (1976) are on the lower side. Therefore, the estimates obtained by Pauly's method (1980a) were considered for estimating the fishing mortality and the exploitation ratio for further analysis of data.

Fishing mortality was estimated as $F = Z - M$ and it was 9.44 $year^{-1}$ and 4.13 $year^{-1}$ for females. Exploitation ratio in the two sexes was estimated as $E = F/Z$ and it was 0.72 and 0.58 respectively.

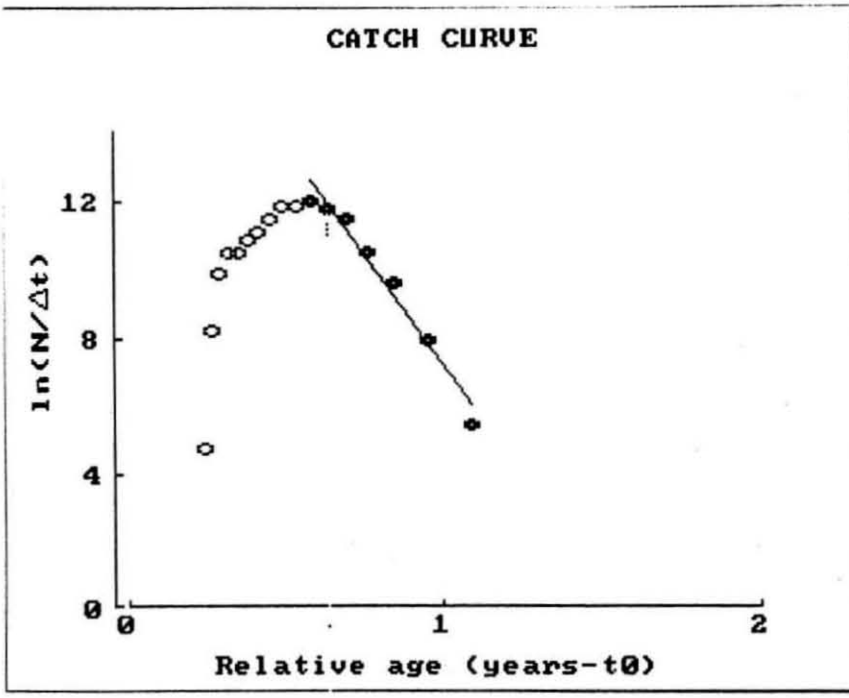

Fig. 35. Catch curve for males

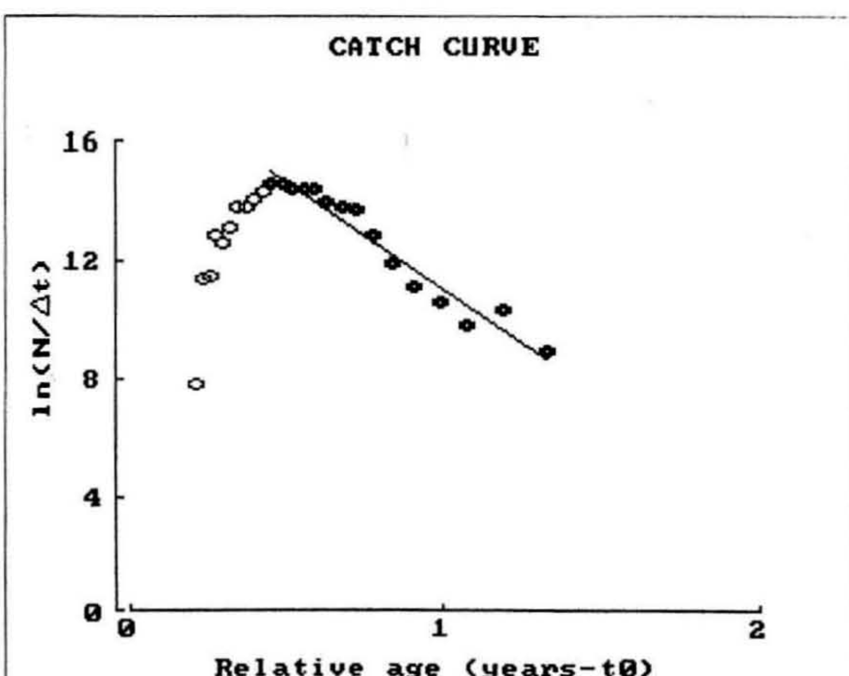

Fig. 36. Catch curve for females

Table 44: Natural mortality estimates by various methods in male and female *M. affinis*

METHOD	NATURAL MORTALITY	
	Male	Female
Pauly (1980a)	3.62	3.05
Alagaraja (1984)	3.8	3.29
Rikhter and Efanov (1976)	3.15	2.69

4.12 Probability Of Capture

Probability of capture and selection curve of male and female *M.affinis* by trawl net were estimated by a programme in which there is a backward extrapolation of the catch curve. The data generated from this were used to estimate the size of prawns at different probabilities of capture and shown in Fig. 37 and 38. The lengths at 25%, 50% and 75% selection by the gear are estimated as

Male:	Female:
L_{25} - 108.25 mm	L_{25} - 108.23 mm
L_{50} - 113.69 mm	L_{50} - 115.21 mm
L_{75} - 118.25 mm	L_{75} - 122.24 mm

4.13 Length Based Cohort Analysis:

Results of cohort analysis in male *M.affinis* are presented in Table 45 for males and Table 46 for females. These tables give the F-array representing the fishing mortality for each length group, total number of male and female present in the sea, their steady stock biomass based on the numbers caught in each size class and the catch in tonnes. In case of males, with terminal fishing mortality 9.55 $year^{-1}$, total catch was estimated to be 443.45 tonnes and biomass to be 170.39 tonnes. Similarly, in case of females, with terminal fishing mortality of 4.94 $year^{-1}$, the catch was 1386.85 tonnes and the biomass 473.43 tonnes. For the two sexes together the catch was 1830.3 tonnes and the biomass was 643.8 tonnes.

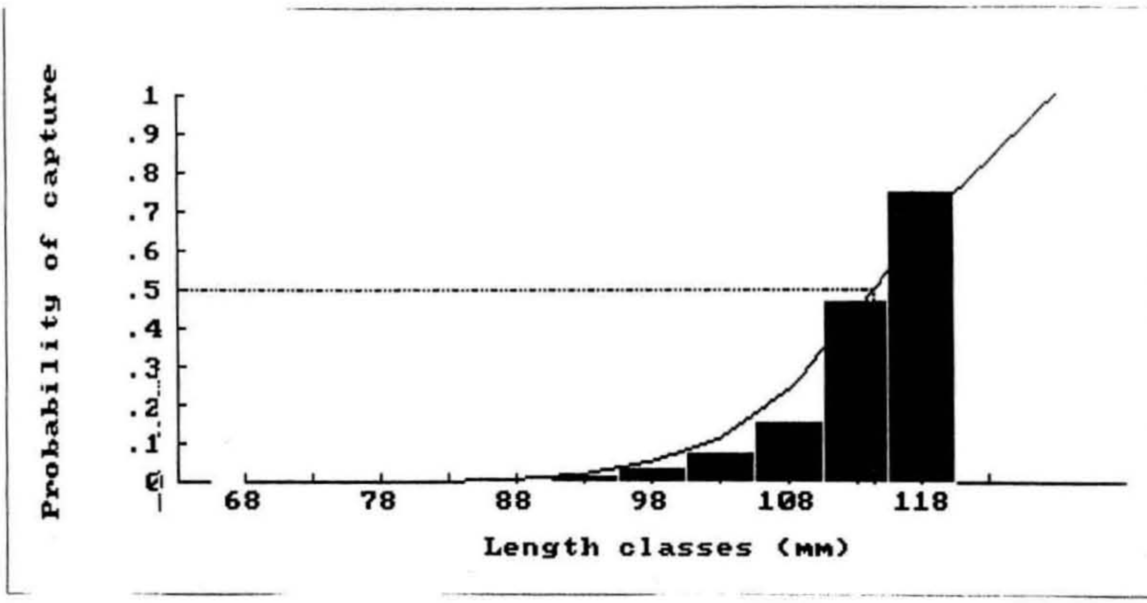

Fig. 37. Selection curve by trawl net for males

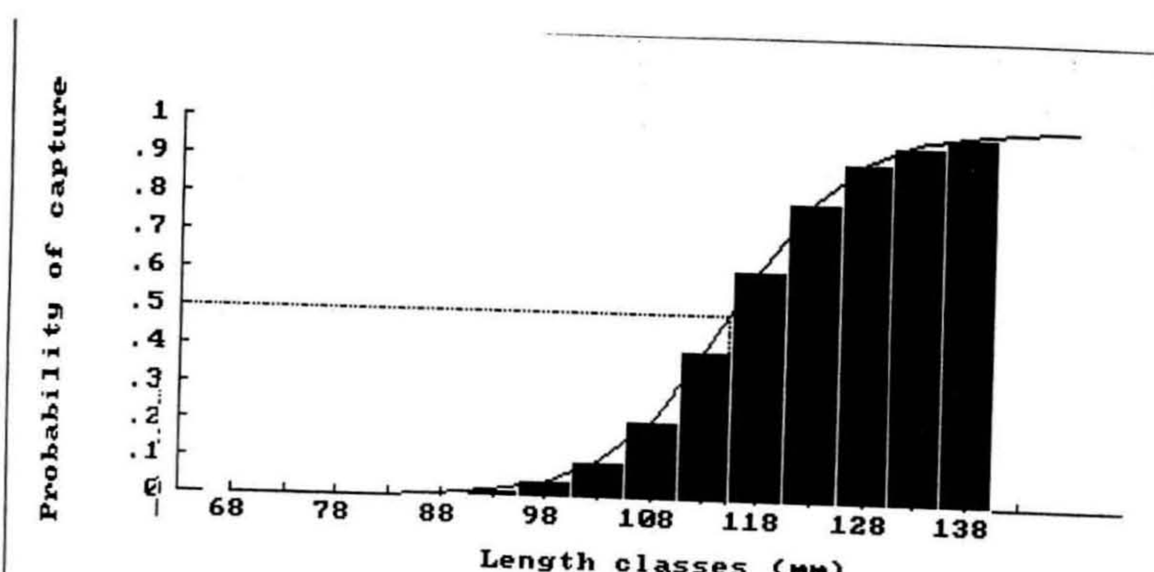

Fig. 38. Selection curve by trawl net for females

Table 45: Cohort analysis for males

SIZE	CATCH (N) (Thousand)	POPULATION (Million)	F. MORTALITY	MEAN N (Millions)	CATCH (Tonnes)	STEADY-STATE BIOMASS
68	2.7	169.81	0.0007	3.85	0	6.92
73	100.6	155.87	0.027	3.72	0.23	8.35
78	563.4	142.3	0.1572	3.58	1.56	9.9
83	1134.9	128.76	0.331	3.43	3.81	11.5
88	1182.9	152.22	0.3626	3.26	4.77	13.14
93	1891.4	102.22	0.6143	3.08	9.06	14.74
98	2539.2	89.19	0.8853	2.87	14.32	16.18
103	3923.8	76.27	1.5011	2.61	25.86	17.23
108	5887.9	62.88	2.5762	2.28	45.01	17.47
113	6066.5	48.72	3.189	1.9	53.44	16.76
118	8163.6	35.77	5.6554	1.44	82.34	14.56
123	6521.9	22.38	6.7709	0.96	74.9	11.06
128	5301.0	12.37	9.8515	0.54	68.96	7
133	2375.1	5.12	9.6231	0.25	34.84	3.62
138	1095.7	1.85	12.1294	0.09	18.04	1.49
143	303.0	0.42	14.6021	0.02	5.58	0.38
148	36.4	0.05	9.55	0.004	0.75	0.08
TOTAL	47090	1206.2		33.90	443.45	170.39

Table 46: Cohort analysis in females

SIZE	CATCH (N) (Thousand)	POPULATION (Million)	F. MORTALITY	MEAN N (Millions)	CATCH (Tonnes)	STEADY-STATE BIOMASS
68	2.78	285.41	0.0005	5.34	0	9.01
73	330.36	269.13	0.0634	5.21	0.71	11.15
78	203.89	252.89	0.0401	5.09	0.54	13.55
83	1002.53	237.16	0.2023	4.95	3.28	16.22
88	803.4	221.05	0.1669	4.81	3.19	19.12
93	1989.9	205.67	0.4274	4.65	9.5	22.22
98	2774.28	189.38	0.6204	4.47	15.75	25.4
103	3511.5	172.96	0.8231	4.27	23.52	28.58
108	4578.06	156.44	1.1353	4.03	35.89	31.61
113	6259.31	139.56	1.6668	3.75	57.02	34.21
118	8697.25	121.85	2.5497	3.41	91.47	35.88
123	10794.4	102.75	3.6122	2.99	130.3	36.07
128	9569.96	82.84	3.7614	2.54	131.85	35.05
133	9487.91	65.51	4.4983	2.11	148.45	33
138	9815	49.59	5.9288	1.65	173.57	29.28
143	7171.06	34.73	5.7782	1.24	142.72	24.7
148	5536	23.77	6.1232	0.9	123.49	20.17
153	4532.8	15.48	7.3612	0.61	112.9	15.34
158	2664.93	9.06	6.7306	0.39	73.86	10.97
163	1318.16	5.19	5.0931	0.26	40.51	7.95
168	826.54	3.08	4.8341	0.17	28.08	5.81
173	1074.36	1.74	4.94	0.22	40.23	8.14
178	0	0	0	0	0	0
183	0	0	0	0	0	0
188	0	0	0	0	0	0
TOTAL	92944.38	2645.24		63.10	1386.85	473.43

4.14 Relative Y/R And Relative B/R Analysis:

Relative Y/R and relative B/R plotted against exploitation rate have been presented in Fig. 39 for males and in Fig. 40 for female *M.affinis*. It is seen that in case of males, the maximum yield per recruit is possible when the exploitation rate, i.e., E_{max} is 0.6773. With the present total mortality coefficient of 13.06 year $^{-1}$ and the Emax of 0.6773 the fishing mortality which gives maximum Y'/R is 8.8455 while the present 'F' is 9.44 year $^{-1}$. Thus, the fishing effort needs to be reduced by 6.3% of the present level. The exploitation rate, at which the biomass per recruit is reduced to 50% of the initial, is 0.3902 but at E_{max} biomass would be reduced to 21% of the biomass at unexploited phase. Similarly, in case of females, E_{max} was estimated as 0.6385 and at the present level of total mortality coefficient of 7.18 year $^{-1}$, the fishing mortality which gives maximum Y'/R is 4.58 year^{-1} while the present level is 4.13 year^{-1} therefore it can be increased by 10% of the present level. The exploitation at which biomass per recruit is reduced to 50% is 0.3636 and at Emax the biomass per recruit would be also 21% of the original.

Figs. 41 and 42 give the yield isopleth diagrams for males and females respectively. From the diagrams it can be seen that maximum yield in case of males can be obtained at L_{50}/L_{∞} = 0.5 instead of the present level of 0.7, i.e., length at capture can be reduced from 113 mm to 81 mm. In case of females it can be reduced from the present level of 0.6 to 0.5, which implies that L_c can be reduced from 115 mm to 102 mm.

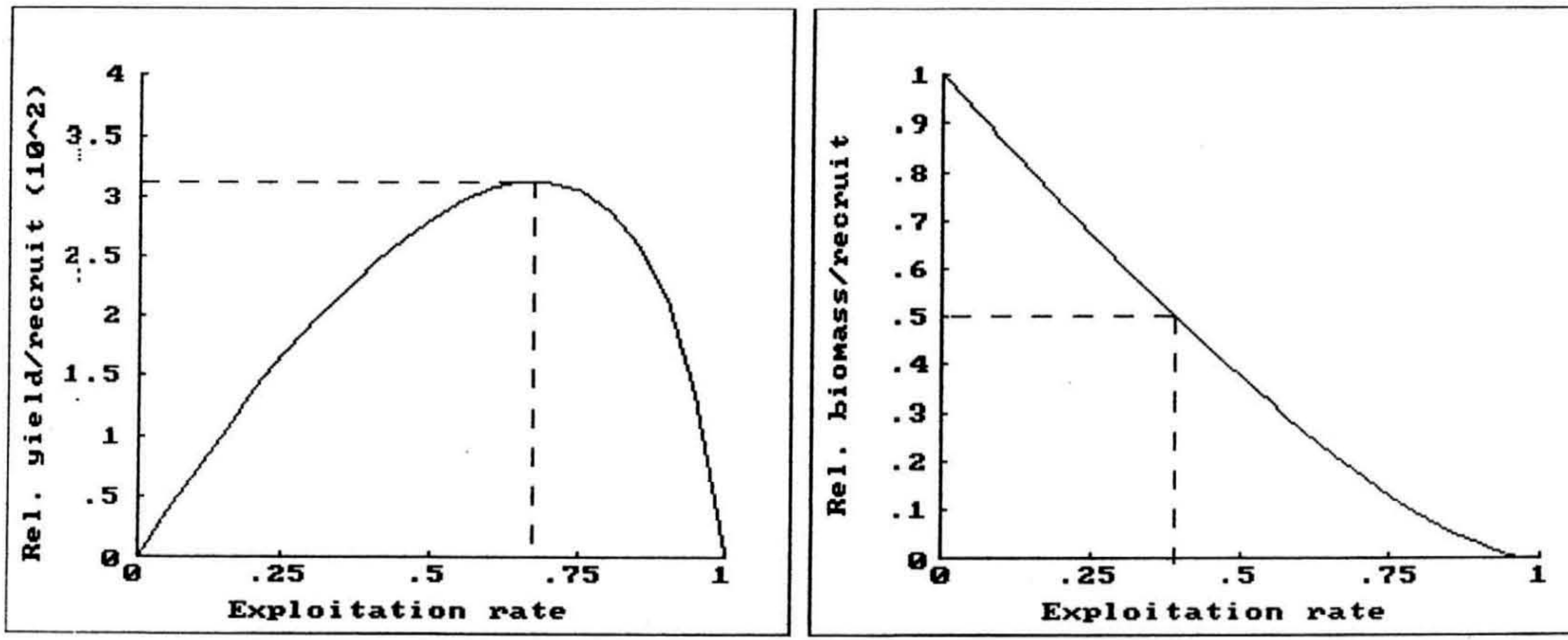

Fig. 39. Y'/R and B'/R plotted against exploitation rate for males

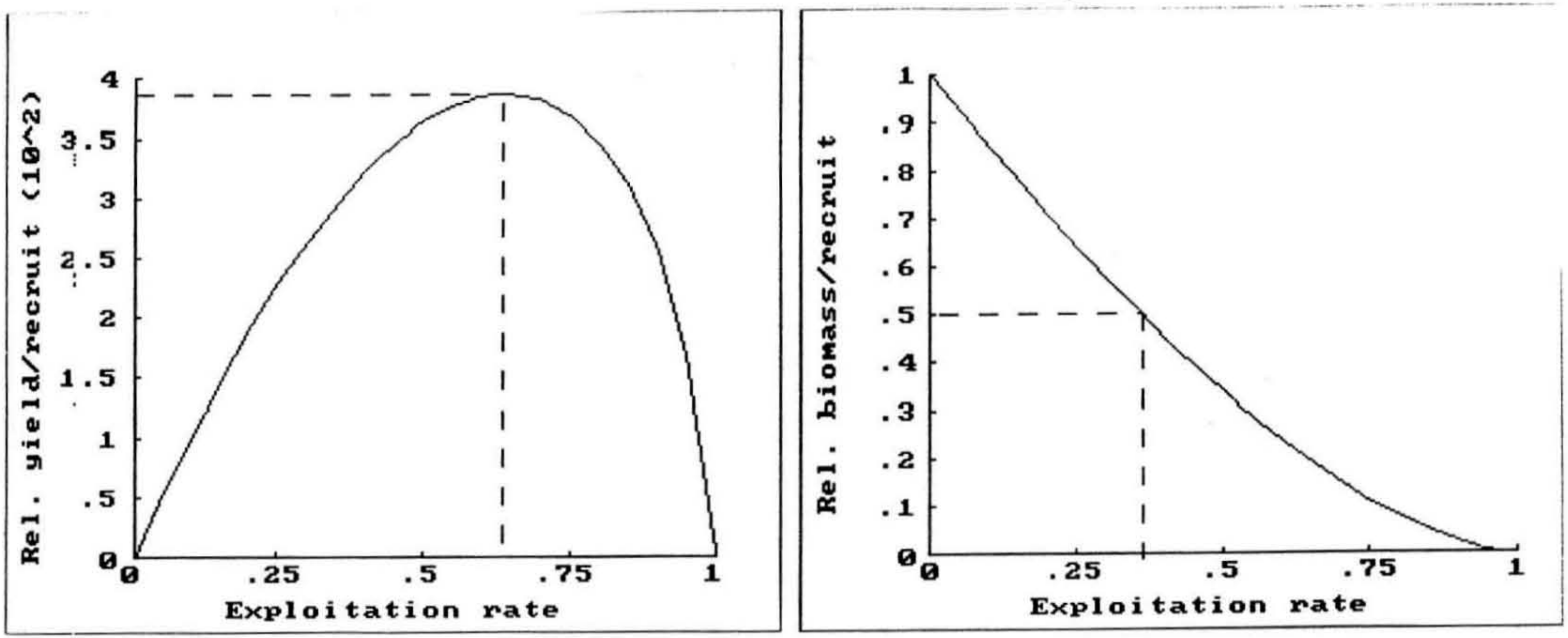

Fig. 40. Y'/R and B'/R plotted against exploitation rate for females

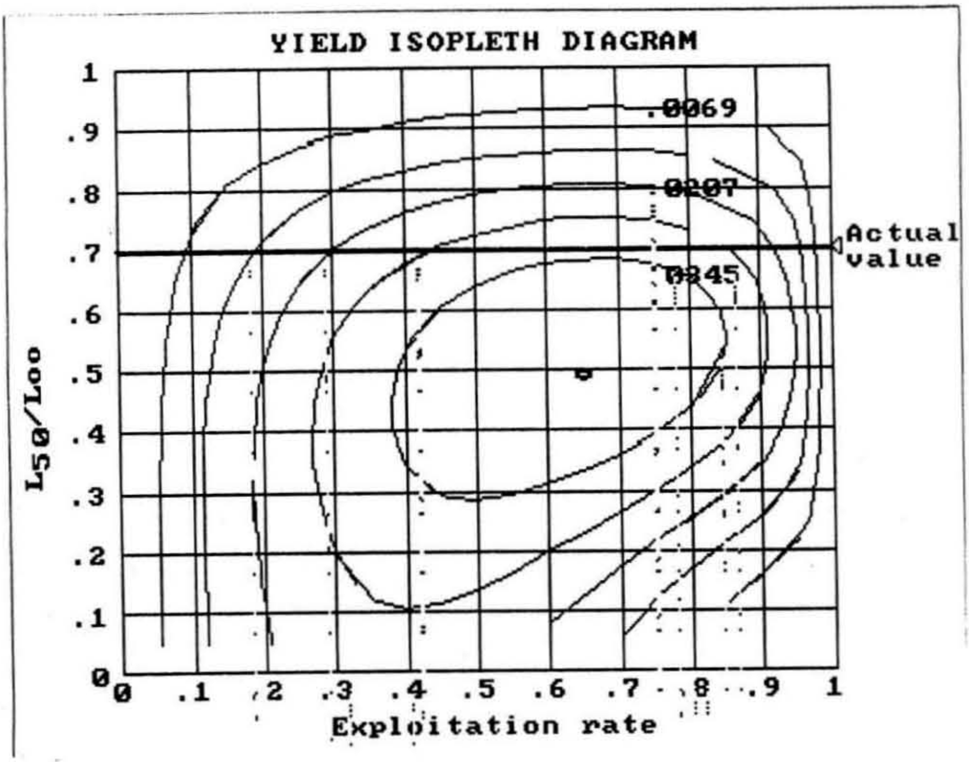

Fig. 41. Yield isopleth diagram for males

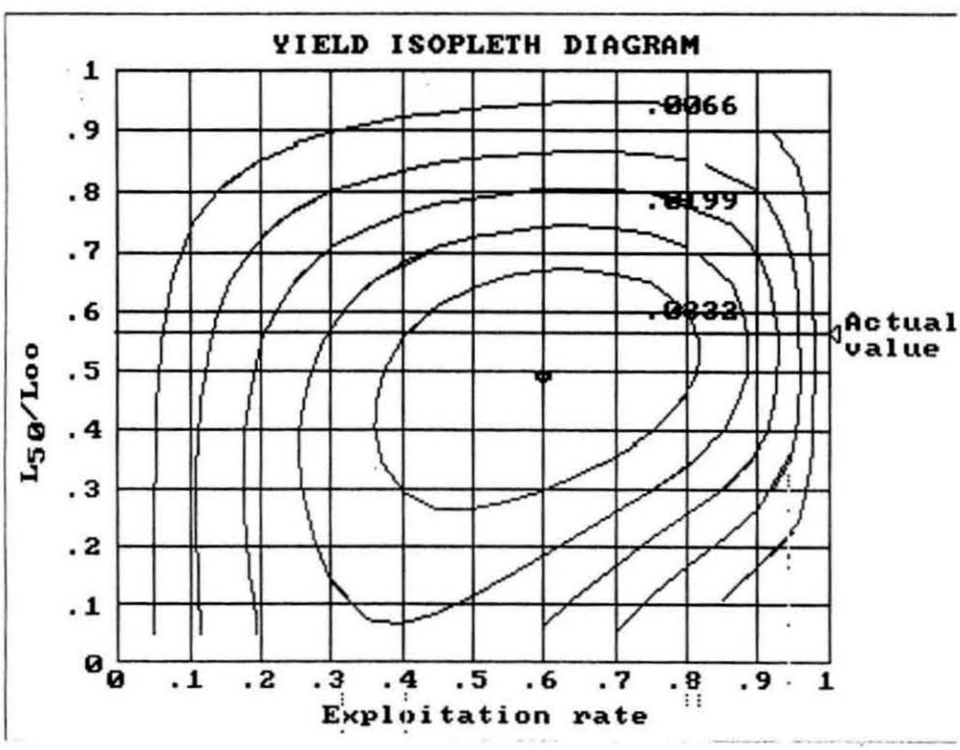

Fig. 42. Yield isopleth diagram for females

4.15 Thompson and Bell Yield and Stock Prediction:

In this method, sizewise wholesale price auctioned at the landing centre was given as Rs 50 per kg for 65 – 100 mm prawns, Rs 70 per kg for 100 – 120 mm prawns, Rs 120 for 120 – 140 mm prawns, Rs 150 per kg for 140 – 160 mm prawns and Rs 180 for a kilogramme of 160 to 190 mm prawns.

Thompson and Bell analysis in the FiSAT package was used to obtain a range of yield, biomass and values of the species corresponding to a range of f factors. Tables 47, 48 and 49 give the yield-stock prediction table for *M.affinis* male, female and the two combined, respectively.

Although sexwise estimates of yield, biomass and value have been obtained, it is difficult to follow any management suggestions for the two sexes separately. Therefore, management suggestions have been drawn by the combination of the two sexes (Table 49). It is seen that the yield of the species in Mumbai waters at present level of fishing (f factor = 1) is 1841.5 tonnes. The analysis indicates that the yield can be increased to a maximum of 1896 tonnes. However, for this marginal increase of 55.5 tonnes the effort required would be almost double (f factor = 1.8). It is interesting to see that the value of yield (catch) would be maximum (Rs 21.7 Crores) if the effort were reduced to 80% (f factor = 0.8) of the present level. At present level of fishing, the value of the catch is Rs 21.58 Crores, which is marginally less than that can be obtained by reducing effort by 20%. However, if the catch were maximised, the value would decrease to Rs 19.76 Crores, which is substantial by Rs 1.82 Crores.

Table 47: Thompson and Bell yield-stock prediction for male

f - factor	Yield (in tonnes)	Biomass (in tonnes)	Value (in crores)
0.00	0.00	361.16	0.00
0.10	167.94	301.26	2.00
0.20	261.06	264.77	2.98
0.30	317.85	240.29	3.49
0.40	355.15	222.65	3.77
0.50	381.13	209.21	3.93
0.60	400.11	198.55	4.01
0.70	414.51	189.81	4.05
0.80	425.78	182.46	4.06
0.90	434.81	176.15	4.06
1.00	442.19	170.64	4.05
1.10	448.38	165.78	4.03
1.20	453.57	161.43	4.00
1.30	457.94	157.51	3.97
1.40	461.68	153.94	3.94
1.50	464.90	150.68	3.91
1.60	467.70	147.68	3.88
1.70	470.22	144.90	3.84
1.80	472.42	142.31	3.81
1.90	474.34	139.90	3.78
2.00	476.01	137.64	3.75
2.10	477.48	135.52	3.72
2.20	478.79	133.52	3.69
2.30	479.95	131.63	3.66
2.40	480.98	129.83	3.63
2.50	481.91	128.13	3.60
2.60	482.77	126.50	3.57
2.70	483.53	124.96	3.55
2.80	484.19	123.48	3.52
2.90	484.77	122.07	3.50
3.00	485.48	120.71	3.48
3.10	486.12	119.41	3.46
3.20	486.67	118.16	3.44
3.30	487.12	116.96	3.42
3.40	487.50	115.80	3.40
3.50	487.81	114.68	3.39
3.60	488.07	113.60	3.37
3.70	488.27	112.56	3.35
3.80	488.42	111.55	3.33
3.90	488.54	110.57	3.32
4.00	488.64	109.62	3.30

Table 48: Thompson and Bell yield-stock prediction for female

f - factor	Yield (in tonnes)	Biomass (in tonnes)	Value (in crores)
0.00	0.00	1369.21	0.00
0.10	484.03	1125.89	7.35
0.20	790.45	956.52	11.71
0.30	991.11	833.84	14.33
0.40	1126.00	742.04	15.90
0.50	1218.54	671.40	16.83
0.60	1283.00	615.73	17.34
0.70	1328.38	570.94	17.59
0.80	1360.52	534.22	17.67
0.90	1383.28	503.63	17.64
1.00	1399.32	477.75	17.53
1.10	1410.46	455.59	17.38
1.20	1417.97	436.38	17.20
1.30	1422.79	419.56	17.00
1.40	1425.59	404.68	16.80
1.50	1426.84	391.42	16.58
1.60	1426.91	379.50	16.37
1.70	1426.09	368.72	16.15
1.80	1424.58	358.91	15.94
1.90	1422.53	349.94	15.74
2.00	1420.07	341.68	15.54
2.10	1417.30	334.05	15.34
2.20	1414.28	326.98	15.15
2.30	1411.08	320.39	14.96
2.40	1407.74	314.23	14.78
2.50	1404.30	308.47	14.61
2.60	1400.79	303.04	14.44
2.70	1397.23	297.93	14.28
2.80	1393.64	293.11	14.12
2.90	1390.03	288.54	13.96
3.00	1386.42	284.20	13.81
3.10	1382.81	280.00	13.67
3.20	1379.22	276.16	13.53
3.30	1375.65	272.42	13.39
3.40	1372.11	268.84	13.26
3.50	1368.59	265.42	13.13
3.60	1365.10	262.15	13.00
3.70	1361.65	259.01	12.88
3.80	1358.24	255.99	12.76
3.90	1354.86	253.09	12.64
4.00	1351.52	250.3	12.53

Table 49: Thompson and Bell yield-stock prediction for ***M. affinis***

f - factor	Yield (in tonnes)	Biomass (in tonnes)	Value (in crores)
0.00	0.00	1730.37	0.00
0.10	651.98	1427.15	9.35
0.20	1051.51	1221.29	14.69
0.30	1308.96	1074.14	17.82
0.40	1481.15	964.68	19.68
0.50	1599.67	880.62	20.75
0.60	1683.11	814.29	21.35
0.70	1742.89	760.75	21.64
0.80	1786.30	716.68	21.73
0.90	1818.10	679.78	21.70
1.00	1841.52	648.40	21.58
1.10	1858.84	621.37	21.41
1.20	1871.55	597.81	21.20
1.30	1880.74	577.07	20.98
1.40	1887.27	558.62	20.74
1.50	1891.74	542.10	20.49
1.60	1894.62	527.18	20.24
1.70	1896.32	513.62	20.00
1.80	1897.01	501.23	19.76
1.90	1896.87	489.84	19.52
2.00	1896.09	479.33	19.28
2.10	1894.78	469.57	19.06
2.20	1893.07	460.50	18.84
2.30	1891.03	452.02	18.62
2.40	1888.73	444.07	18.41
2.50	1886.25	436.60	18.21
2.60	1883.57	429.55	18.02
2.70	1880.76	422.90	17.83
2.80	1877.83	416.59	17.64
2.90	1874.81	410.61	17.46
3.00	1871.90	404.92	17.29
3.10	1868.94	399.50	17.13
3.20	1865.89	394.33	16.97
3.30	1862.78	389.38	16.81
3.40	1859.61	384.65	16.66
3.50	1856.40	380.11	16.51
3.60	1853.17	375.75	16.37
3.70	1849.92	371.57	16.23
3.80	1846.67	367.54	16.09
3.90	1843.41	363.66	15.96
4.00	1840.16	359.92	15.83

4.16 Stock Recruitment Relationship:

In order to examine the stock recruitment relationship in *M. affinis* in Mumbai waters, length-frequency data raised to the monthly catch and the monthly maturity distribution of females collected by Mumbai Research Centre of CMFRI for the period of four years from December 1997 to November 2001 was used. The data were subjected to monthly cohort analysis by giving natural mortality and K on monthly basis, as inputs. Monthwise size distribution of estimated numbers of the prawns present in the sea, was thus obtained. The number of females larger than the size-at-maturity (114 mm) was considered as spawning stock in a particular month and the males and females less than 114 mm in total length together were considered as recruits. The smallest size group available in the catch was 66-70 mm in total length, which consisted of about three months old juveniles. Monthwise number of mature females (stage III and IV) in each size class and month was also estimated by multiplying the total number of females by the proportion of mature females available in the corresponding size class. The estimated number of adult females, mature females and recruits thus obtained are presented in Tables 50, 51 and 52 respectively. A scatter of points was obtained by plotting the numbers of spawning females (S) in a particular month against the number of recruits (R) three months later. Similarly, a scatter of points was obtained by plotting the number of mature females (S') and the number of recruits (R). These are presented in Figs. 43 and 44 respectively.

Linear regression of number of adult females (S) against number of recruits (R) gave following parameters:

a = 57672963 (s. e. = 44671155) or $5.7 * 10^{7}$ (s.e. = $4.4 * 10^{7}$)

$b = -0.3714$ (s. e. = 0.4915)

$r^2 = 0.0137$ ($r = 0.12$)

With the parameters 'a' and 'b', the stock recruitment relationship can be represented as:

$R = 57672963 - 0.3714\,(S)$

Similarly, simple linear regression of number of mature females (S') against number of recruits (R) gave the following parameters:

$a = 64713640$ (s. e. = 42402944) or $6.4 * 10^7$ (s.e. = $4.2 * 10^7$)

$b = -1.4885$ (s. e. = 0.7263)

$r^2 = 0.0950$ ($r = 0.31$)

The relationship can be represented as:

$R = 64713640 - 1.4885\,(S')$

It is seen that the correlation coefficient 'r' is very poor in both the relations.

The two classical models of stock recruitment relationship were fitted to the data by regression of S against S/R in case of Beverton and Holt model and S against Ln (R/S) in case of Ricker model.

Table 50: Sizewise estimated number of adult females during December 1997 to November 2001

MONTH / SIZE	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98	Oct-98	Nov-98
113	7966740	5760309	2887048	1802840	1303488	1033170	51593	938139	3459392	2528108	2387349	3655904
118	7302540	5502672	2704266	1727964	1237416	958120	48323	870511	3261940	2302810	2030130	3410336
123	6425466	5253056	2502154	1638586	1157712	846011	45055	749076	2777072	2051103	1699948	3120258
128	5424162	4824281	2244643	1523835	1052975	717457	40039	582339	2250492	1814464	1326372	2799877
133	4368851	3879124	1891114	1335982	899341	577624	31436	393822	1857144	1589103	834493	2453559
138	3243118	2734471	1447298	1015568	703758	405892	22247	254989	1544334	1390035	392375	1956865
143	2177151	1842417	969538	735402	512018	232522	15209	152824	1255214	1157642	161866	1501716
148	1394321	1026045	484425	483448	327110	134136	8929	363203	936910	918393	71698	1139557
153	784385	436394	258090	284194	183722	336623	18583		658272	645082	42058	802345
158	382098	230467	168680	163266	112556				1495417	356302	30534	442746
163	175880	497180	295120	281470	236027					183626	66383	688217
168	245726									116393		
173										68896		
178										71030		
183												
188												
TOTAL	39890436	31986415	15852376	10992556	7726123	5241556	281414	4304903	19496185	15192987	9043205	21971378

MONTH SIZE	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Jun-99	Jul-99	Aug-99	Sep-99	Oct-99	Nov-99
113	2499932	2049124	1277536	1456156	2640190	807050	626075	1661280	2693835	1604501	4253156	4760200
118	2292860	1748125	1178437	1348968	2484630	764419	606484	1425950	2279309	1354956	4053080	4521469
123	1981087	1390360	1055854	1228940	2313258	695663	585765	1185699	1873632	1110955	3703913	4145676
128	1697154	1010048	880789	1066054	1997612	597723	560211	959806	1625456	896555	3187023	3574373
133	1498591	735888	653710	864595	1517670	489359	523502	725973	1299599	714188	2549779	2923518
138	1296957	539414	449162	664951	985977	384036	462688	537647	931779	466018	2008418	2089739
143	1087993	411794	264533	467798	607435	282564	371640	413593	743694	238425	1510079	1456265
148	906988	326739	119365	304176	380442	177309	256171	273570	494801	142206	1033977	937390
153	713331	257982	230920	199497	170566	93753	152855	168821	995193	89901	595447	514242
158	506959	171857		130303	251537	186753	58131	124998		181683	316235	265367
163	290647	97197		87084			59940	280450			165617	414143
168	413333	165937		44962							75996	
173				47523							104333	
178												
183												
188												
TOTAL	15185832	8904465	6110306	7911007	13349316	4478629	4263461	7757786	12937298	6799389	23557053	25602382

MONTH / SIZE	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00
113	7893553	3081788	1895174	2487558	1616334	1889804	857597	481342	2467592	11473223	8008432	3063608
118	7131121	2754010	1824382	2389142	1533183	1779074	779585	415866	2003701	10367537	7351521	2846197
123	6363669	2381839	1726982	2280292	1458568	1659278	718668	355159	1460140	9035473	6176432	2563860
128	5716872	1899757	1572339	2154904	1376005	1520554	674868	305287	1070743	7540982	4901787	2205707
133	5033981	1489377	1352734	1986504	1266617	1328681	618627	253835	836334	6095347	3780875	1747214
138	4178151	1219183	1058070	1747299	1122387	1122870	531922	189393	542129	4762820	2569684	1353634
143	3468965	961157	711454	1394011	934412	947768	436316	138419	323142	3615271	1609870	927965
148	2889856	732757	423770	983489	744327	788305	338373	107817	220187	2662135	1035657	539191
153	2056183	532096	203061	613969	567953	612147	259758	74766	566533	1956462	2586133	295766
158	1355941	369113	61330	375829	381734	408704	185397	42161		1514790		171391
163	1013627	266105	20332	215867	187883	259911	124252	24407		1193445		67495
168	852168	515833	35633	120734	57593	181359	87090	15286		839448		52333
173	700314			189900	19527	92829	57798	23167		1263867		
178	1006233				25067	40508	37512					
183						43867	41367					
188												
TOTAL	49660632	16203015	10885263	16939498	11291590	12675658	5749129	2426903	9490502	62320798	38020390	15834360

MONTH / SIZE	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Aug-01	Sep-01	Oct-01	Nov-01
113	8097888	1692168	1409758	1089296	808728	621286	666439	0	2361014	4659796	2123564	1305605
118	7331127	1603910	1344104	1041999	759351	578501	640451	0	1551326	4358825	2020492	1217345
123	6565828	1445843	1248103	988528	694751	541602	612390	0	1077702	3956072	1899140	1132482
128	5895768	1259790	1123753	910287	637522	508416	578914	0	719228	3486607	1775513	1018486
133	5206705	1032984	957407	812046	566226	471963	545992	0	2167593	2708752	1648918	865170
138	4317323	722842	721781	692308	452639	435609	497809	0		1814776	1481806	576694
143	3500887	430254	461673	565198	319703	367387	420166	0		1147321	1237113	347243
148	2874948	272926	252036	414054	217370	244596	311909	0		3049463	832583	211945
153	2099817	729560	136993	226983	142417	146766	180807	0			446626	124240
158	1412574		296243	104370	86669	85324	84270	0			888667	68217
163	1032621			39970	51015	43947	137927	0				33950
168	852204			42923	84407	69790		0				
173	700345											
178	1006283											
183												
188												
TOTAL	50894316	9190276	7951850	6927963	4820798	4115187	4677072	0	7876862	25181612	14354422	6901376

Table 51: Sizewise estimated number of mature females during December 1997 to November 2001

MONTH SIZE	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98	Oct-98
113	2947694	5760309	320751	1802840	977616	0	51593	938139	864848	210339	0
118	3651270	1100534	600888	1382371	651252	718590	4832	87051	1535069	121128	451095
123	3668941	2626528	1000862	1456539	680966	846011	19712	327721	1388536	683633	700039
128	3773047	2412140	1836566	1142876	368541	448411	14750	214534	1323740	777679	742768
133	2912276	2830596	882394	1081478	391034	519861	18862	236293	928572	953462	667594
138	2378178	1867370	940744	761676	450405	180379	13348	152993	1187902	772164	245234
143	1654635	1364678	570282	635093	435215	139513	12673	127348	920448	612856	107900
148	1066237	758350	430557	458019	218084	89415	5102	207534	624544	667947	71698
153	627508	339384	258090	142097	183722	0	18583	0	246852	501681	28036
158	218331	153629	168680	163266	112556	0	0	0	1495417	207831	15267
163	175880	497180	295120	187740	177020	0	0	0	0	146901	66383
168	0	0	0	0	0	0	0	0	0	116393	0
173	0	0	0	0	0	0	0	0	0	34448	0
178	0	0	0	0	0	0	0	0	0	71030	0
183	0	0	0	0	0	0	0	0	0	0	0
188	0	0	0	0	0	0	0	0	0	0	0
TOTAL	23073996	19710699	7304934	9213996	4646411	2942180	159456	2291614	10515926	5877491	3096014

MONTHH SIZE	Nov-98	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Jun-99	Jul-99	Aug-99	Sep-99
113	1218513	961474	922106	91216	832047	1759950	0	0	1107409	2020376	534780
118	1549998	2116539	828087	261849	1103591	1580970	382209	0	1307026	1519387	104196
123	1650304	1131993	858686	333439	1106046	1601469	521747	0	889274	1498906	370281
128	2053149	1234340	606029	660592	973308	1639040	313087	186718	799806	1219092	348580
133	1635542	832467	389579	207945	714242	1264674	285443	290805	557693	866313	190403
138	1330668	825254	485473	179665	372373	733764	281614	299359	460817	745423	233009
143	1051201	815994	247077	151154	345750	573661	131844	297312	236327	0	110033
148	964179	362795	245054	85262	283887	355066	159578	197047	218856	0	85324
153	510532	407597	171971	230920	149623	124036	80356	95534	168821	0	64207
158	272377	126740	137486	0	130303	251537	186753	37611	124998	0	0
163	688217	96786	97197	0	87084	0	0	59940	280450	0	0
168	0	413333	0	0	44962	0	0	0	0	0	0
173	0	0	0	0	0	0	0	0	0	0	0
178	0	0	0	0	0	0	0	0	0	0	0
183	0	0	0	0	0	0	0	0	0	0	0
188	0	0	0	0	0	0	0	0	0	0	0
TOTAL	12924681	9325312	4988744	2202042	6143214	9884168	2342632	1464326	6151477	7869497	2040814

MONTH / SIZE	Oct-99	Nov-99	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00
113	4253156	0	3675920	2266881	0	248745	604921	1889804	355420	281071	1368198
118	2026540	1808587	4317344	1519344	732256	879542	1533183	1717506	600922	177919	1127165
123	1157473	1594427	4201235	1486920	1126370	2280292	0	1576492	670865	164491	1000840
128	796756	2118174	2684748	1432909	1279897	1031760	1376005	781535	674868	243678	724708
133	1529868	1915196	2446477	1285420	1051445	1816193	891200	985563	403785	104300	746055
138	926885	1451115	2336170	901565	952848	1407991	900146	741346	405857	88223	490766
143	1069589	794247	2119920	828879	684982	921942	739944	570365	316962	113370	323142
148	664641	771941	1452453	607246	379897	752885	488911	508636	283254	107817	220187
153	238179	462818	1961843	366949	210465	483710	579738	350465	230528	73188	95237
158	0	212293	899982	356778	0	322452	354671	220268	177210	28788	0
163	0	0	1013605	266105	0	189900	117548	146259	89689	24407	0
168	0	0	852168	0	0	120760	52959	90454	0	2761	0
173	0	0	700314	0	0	189900	19527	35826	57798	0	0
178	0	0	1006233	0	0	0	0	0	37512	0	0
183	0	0	0	0	0	0	0	0	0	0	0
188	0	0	0	0	0	0	0	0	0	0	0
TOTAL	12663086	11128798	29668411	11318996	6418161	10646072	7658752	9614520	4304671	1410012	6096299

MONTH / SIZE	Sep-00	Oct-00	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01
113	6757288	1601160	2158137	4723498	0	0	363062	539098	414149	0	0
118	6123341	5612337	2283991	5997595	641564	1344104	694597	442929	495833	640451	0
123	6118260	3200183	2236741	2777345	481900	970650	790822	416851	135401	153097	0
128	6491212	3047932	1569502	3316369	1007832	2160977	455144	398451	338910	289457	0
133	4316189	3465532	1625017	2928772	425279	866166	609035	333054	471963	181979	0
138	3607541	2485074	1134948	2158662	397563	1045283	538408	330743	326706	271306	0
143	3311750	1359134	866507	2722640	258152	384712	403552	239778	183694	243234	0
148	2384571	709976	516675	1437474	90966	207551	301100	167201	139762	173265	0
153	1548163	2586133	158854	2099817	729560	114157	196023	118676	118807	129097	0
158	1349661	0	171391	1412574	0	236995	78277	65002	42662	42135	0
163	1193445	0	0	516310	0	0	31976	38262	37667	0	0
168	839448	0	0	0	0	0	0	84407	46522	0	0
173	653256	0	0	0	0	0	0	0	0	0	0
178	0	0	0	0	0	0	0	0	0	0	0
183	0	0	0	0	0	0	0	0	0	0	0
188	0	0	0	0	0	0	0	0	0	0	0
TOTAL	44694124	24067461	12721763	30091055	4032816	7330594	4461995	3174451	2752076	2124020	0

MONTH / SIZE	Aug-01	Sep-01	Oct-01	Nov-01
113	1180507	0	530891	783363
118	581747	1307647	621503	811482
123	0	1078821	632983	808592
128	287691	1743303	955936	452615
133	0	2230657	1498866	732020
138	0	1036963	1126173	471793
143	0	491627	666061	243070
148	0	3049463	693792	84778
153	0	0	362884	93180
158	0	0	799800	34109
163	0	0	0	33950
168	0	0	0	0
173	0	0	0	0
178	0	0	0	0
183	0	0	0	0
188	0	0	0	0
TOTAL	2049945	10938483	7888890	4548952

Table 52: Sizewise estimated number of recruits during December 1997 to November 2001

MONTH / SIZE	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98	Oct-98	Nov-98
68	19736037	11823366	6671311	3641499	2700403	3152771	100170	2543325	9889179	6890557	7860550	9230228
73	19228281	11530714	6502735	3551400	2633274	3066809	97741	2476279	9628319	6710235	8429162	8995692
78	18709926	11232154	6330687	3459484	2564781	2974403	95264	2407799	9361889	6526085	8192786	8756315
83	18180126	10927240	6140823	3365611	2494826	2878091	92735	2337782	9089458	6337819	7951037	8482517
88	17637970	10615458	5939914	3269625	2423290	2764523	90150	2266089	8810522	6142247	7700094	8123404
93	17082397	10296269	5738444	3171359	2350044	2623395	87247	2192583	8523924	5927347	7439376	7678519
98	16439298	9969006	5487787	3070609	2274938	2480025	83910	2117093	8219118	5707319	6979893	7154993
103	15659260	9611640	5221762	2958955	2197790	2362296	79552	2037045	7789332	5474818	6307530	6639066
108	14643503	9209596	4945695	2830977	2105604	2216261	73198	1947357	7254213	5163770	5597912	6180224
TOTAL	157316798	95215441	52979157	29319519	21744951	24518573	799966	20325352	78565953	54880198	66458341	71240957

MONTH / SIZE	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Jun-99	Jul-99	Aug-99	Sep-99	Oct-99	Nov-99
68	5628321	4677913	3610283	3030173	5010974	1841418	872910	6258236	8450877	5005596	10468666	14166135
73	5492898	4561872	3516507	2955848	4890124	1794526	853802	6090457	8229335	4873858	10197964	13794259
78	5354813	4443485	3420751	2880033	4766889	1746664	834353	5917341	8003077	4739313	9921589	13414476
83	5213868	4322573	3320513	2802617	4641096	1697756	814542	5740377	7747917	4601744	9639083	13005557
88	5057836	4198932	3208208	2719475	4512542	1647716	794342	5560937	7471440	4456102	9349956	12580123
93	4871815	4068675	3083419	2619638	4376653	1596451	773728	5332908	7185770	4302033	9053645	12091017
98	4614803	3919344	2936918	2512447	4234360	1543850	752672	5013030	6658709	4101504	8749478	11442150
103	4262296	3730071	2766199	2407719	4066369	1488241	731136	4558171	6088165	3849575	8418092	10736045
108	3848354	3385272	2467867	2269849	3845954	1417801	708296	3961771	5410662	3551005	8046867	9868674
TOTAL	44345003	37308137	28330664	24197799	40344960	14774423	7135783	48433227	65245951	39480728	83845340	111098434

MONTH / SIZE	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00
68	16481922	5855593	7515548	5577912	3819661	3800525	2131601	1690931	7519105	28184592	20428328	8758993
73	16082383	5715066	7306029	5436882	3723346	3707787	2073365	1646930	7321082	27459872	19886609	8521695
78	15654013	5571784	7091834	5292851	3623063	3613201	2000411	1602001	7100095	26702314	19310473	8267173
83	15181326	19985381	6871870	5143700	3516570	3514234	1908205	1556070	6852573	25845067	18661365	7982808
88	14645110	5275569	6646452	4984810	3396426	3409725	1806833	1501612	6602280	24918284	17970075	7677451
93	14081355	5121898	6415542	4811887	3253076	3292485	1688514	1424047	6325966	23858358	17261447	7305638
98	13340900	4952753	6163961	4626835	3091968	3151346	1557260	1305642	5953525	22670479	16472109	6901745
103	12414567	4738064	5905141	4408277	2888697	3006250	1427861	1134290	5444696	21425839	15481117	6470343
108	11360545	4456092	5647854	4189464	2652333	2828773	1306014	938262	4748571	19614451	14447511	5890781
TOTAL	129242121	61672198	59564232	44472617	29965139	30324325	15900065	12799785	57867893	220679256	159919033	67776626

MONTH / SIZE	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Aug-01	Sep-01	Oct-01	Nov-01
68	13763427	3029099	2294937	3079226	1951883	1107490	1445137	0	14093689	11040387	3967588	3410899
73	13452222	2956673	2241696	2997783	1902069	1081367	1408897	0	13714873	10759231	3872129	3324219
78	13127159	2882830	2187443	2914600	1851217	1054740	1371917	0	13274471	10472240	3774899	3235748
83	12764870	2807471	2132110	2829540	1799254	1027574	1334139	0	12763579	10164124	3675655	3145347
88	12379503	2730472	2075612	2742443	1746087	999825	1295500	0	12098339	9842959	3574244	3042174
93	11992163	2651710	2017869	2649142	1686867	971451	1255929	0	11426474	9503757	3470497	2920255
98	11515501	2571036	1954470	2550016	1605990	942401	1212559	0	10570809	9106935	3360858	2746227
103	10975915	2479608	1889855	2452459	1524247	906720	1168231	0	9145361	8700782	3211620	2504560
108	10344817	2372122	1828100	2329179	1422341	849022	1119090	0	7184707	8231846	3031516	2230966
TOTAL	110315577	24481022	18622091	24544387	15489956	8940590	11611397	0	104272301	87822261	31939006	26560394

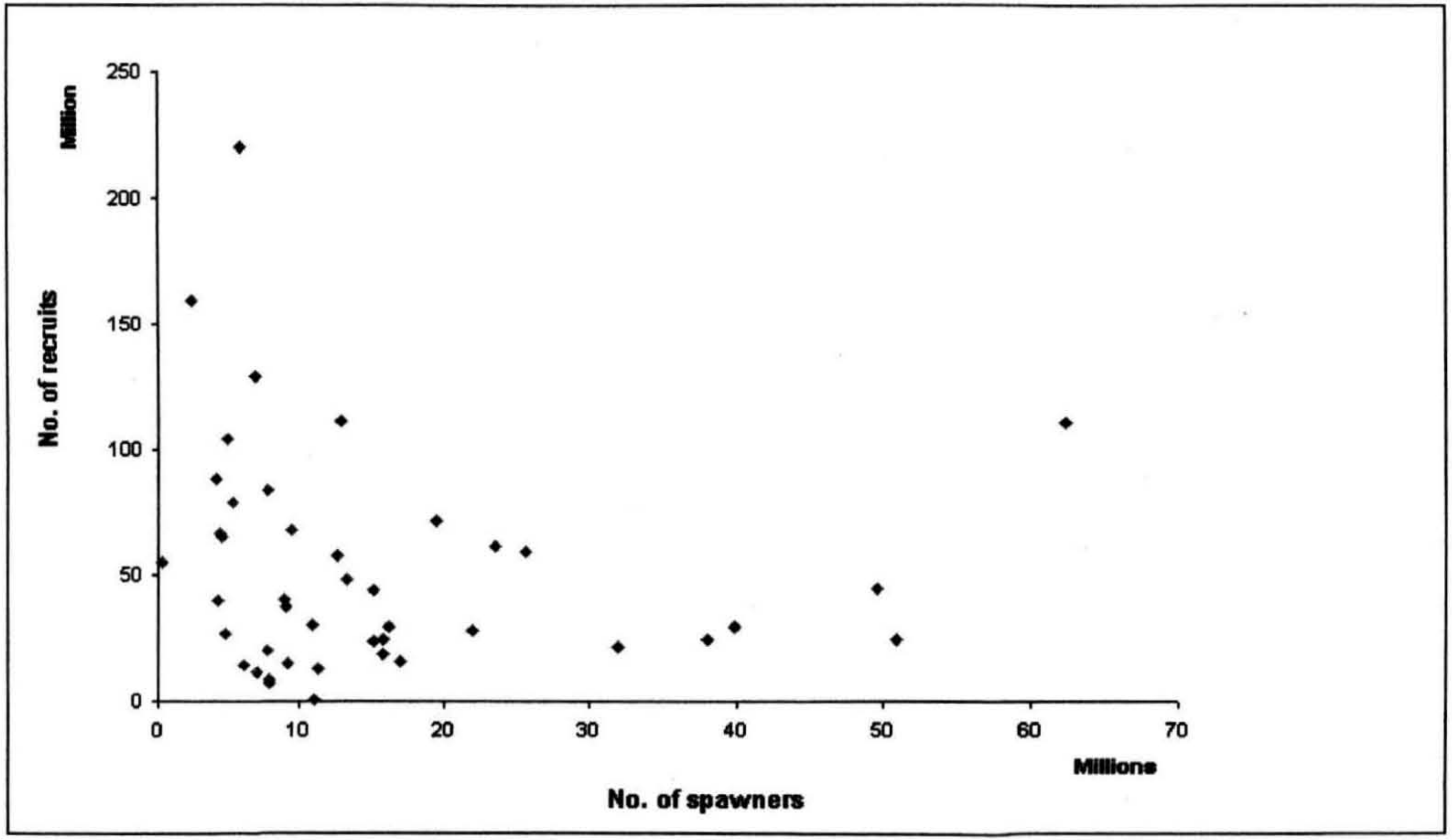

Fig. 43: Relationship between total number of adult females (stock) and number of juveniles three months later (recruit)

4.16.1 Beverton and Holt model

Linear regression of S against S/R (no. of adult females and recruits) was carried out and the parameters obtained were:

$\alpha = 1.7 * 10^{-8}$ (s. e. = $2.3 * 10^{-8}$)
$\beta = 0.5534$ (s. e. = 2.0869)
$r^2 = 0.0132$ (r = 0.11)

The relationship can be given as:

$R = 1/[1.7 * 10^{-8} + (0.5534/S)]$

Linear regression of S' against S'/R (no. of mature females and recruits) was carried out and the parameters obtained were:

$\alpha = 4.2 * 10^{-8}$ (s. e. = $3.01 * 10^{-8}$)
$\beta = 0.2353$ (s. e. = 1.7592)
$r^2 = 0.0464$ (r = 0.21)

The relationship can be given as:

$R = 1/[4.2 * 10^{-8} + (0.2353/S')]$

The resulting curves obtained by plotting S and R are shown in Figs. 44 and 45. The Beverton and Holt model gave an asymptotic curve indicating that at high stock levels recruitment becomes constant. *M. affinis* does not appear to follow this curve since the coefficient of correlation 'r' was found to be very low and the standard errors of the estimates were very high.

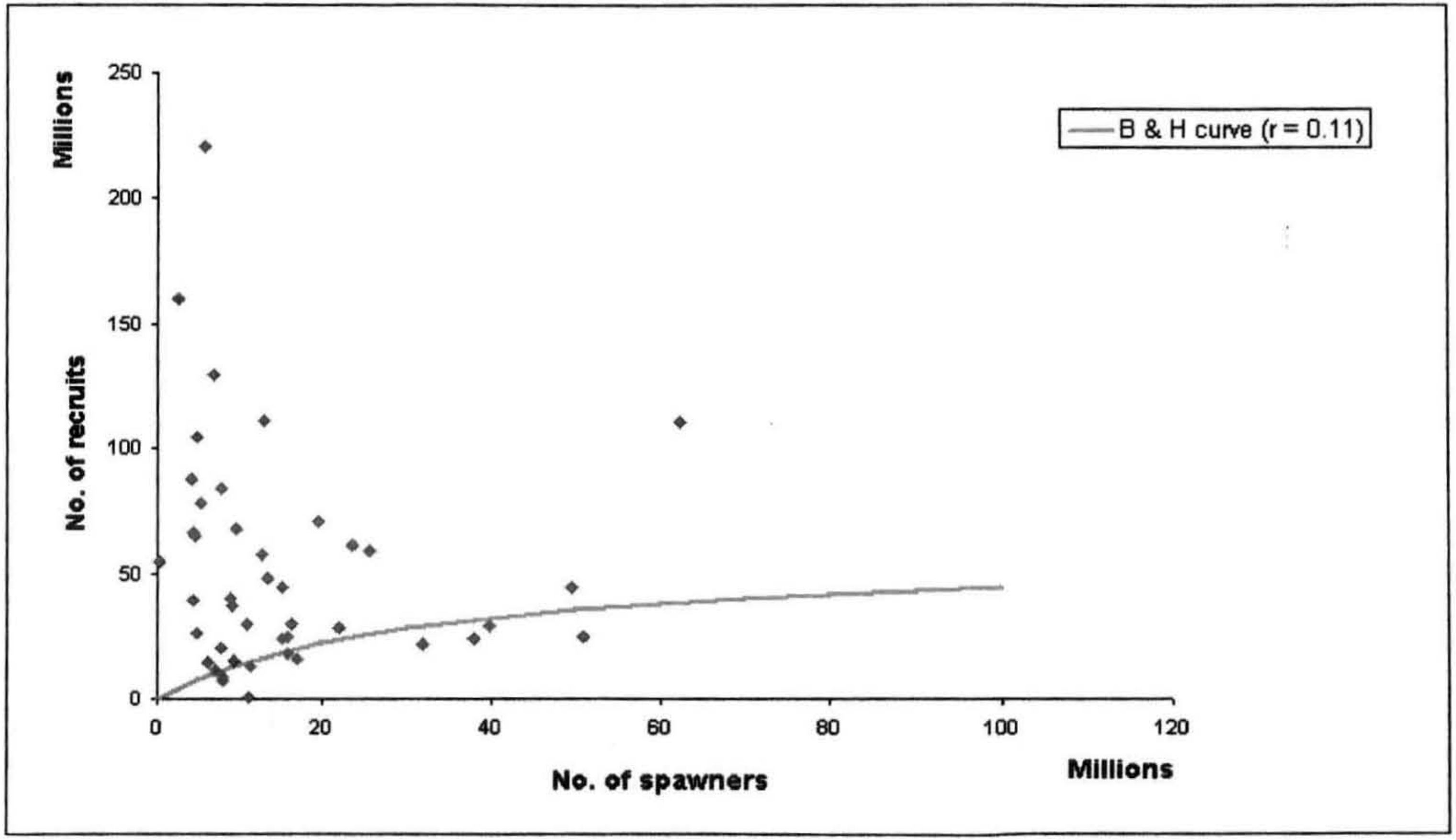

Fig. 45: Beverton and Holt curve fitted to the stock recruitment relationship (S - S/R)

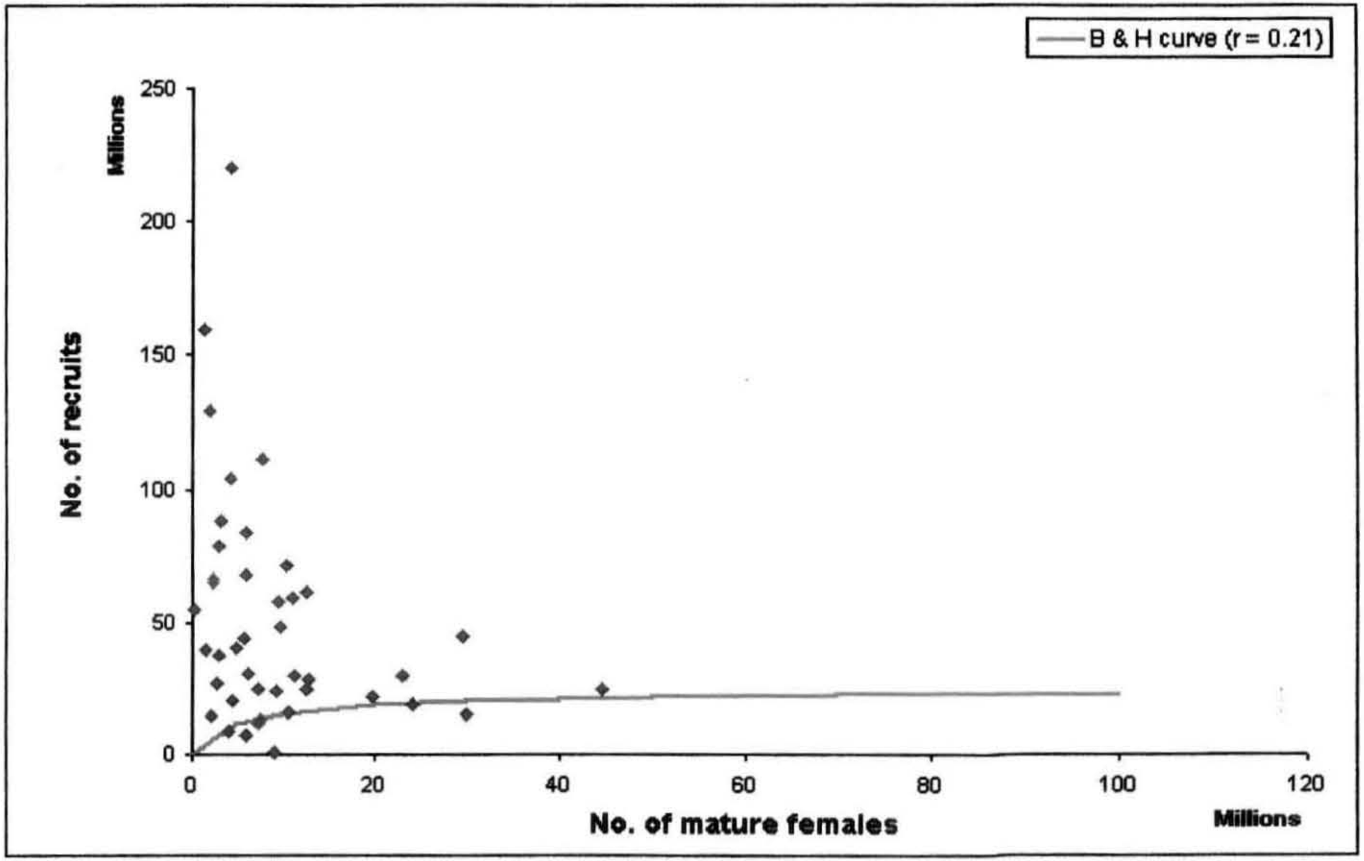

Fig. 46: Beverton and Holt curve fitted to the stock recruitment relationship (S' - S'/R)

4.16.2 Ricker model:

Linear regression of S (no. of adult females) against Ln (R/S) was carried out and the parameters obtained were:

$a = 2.0923$ (s. e. = 1.2541)
$b = -5.7 * 10^{-8}$ (s. e. = $1.38 * 10^{-8}$)
$r^2 = 0.3518$ (r = 0.54)

The relationship can be given as:

$$R = S * \text{Exp}\,[2.0923 - (5.7 * 10^{-8} * S)]$$

Linear regression of S' (no. of mate females) against Ln (R/S') was carried out and the parameters obtained were:

$a = 2.7992$ (s. e. = 1.2365)
$b = -1.1 * 10^{-7}$ (s. e. = $2.12 * 10^{-8}$)
$r^2 = 0.4205$ (r = 0.65)

The relationship can be represented as:

$$R = S * \text{Exp}\,[2.7992 - (1.1 * 10^{-7} * S')]$$

The resulting curves obtained by the expressions are presented in Figs 46 and 47. *M. affinis* stock showed better coefficient of correlation (r = 0.65) thus appears to follow the Ricker model of stock recruitment relationship. Correlation coefficient 'r' is better when the number of mature females, instead of the total number of females, is considered as the spawning stock. The Ricker model explains density dependent changes in recruitment of the stock. According to this model recruitment decreases at high stock levels because of density dependent control mechanisms such as cannibalism, amount of food, space etc.

Ricker curve fitted to stock (total adult females) – recruit relationship indicated that maximum recruitment is possible at stock level of 20 million spawners. This would result in 52 million recruits in three months time. Recruitment level is low with less than 10 million spawners and it falls again if the spawning stock is larger than 40 million. Therefore, largest recruitment is possible with a spawning stock of 10 – 40 million adult females. Similarly, maximum recruitment can be expected when there are 10 million mature females. This would result in 55 million recruits three months later. About 5 – 20 million mature females would ensure good recruitment of 35 to 55 million juveniles.

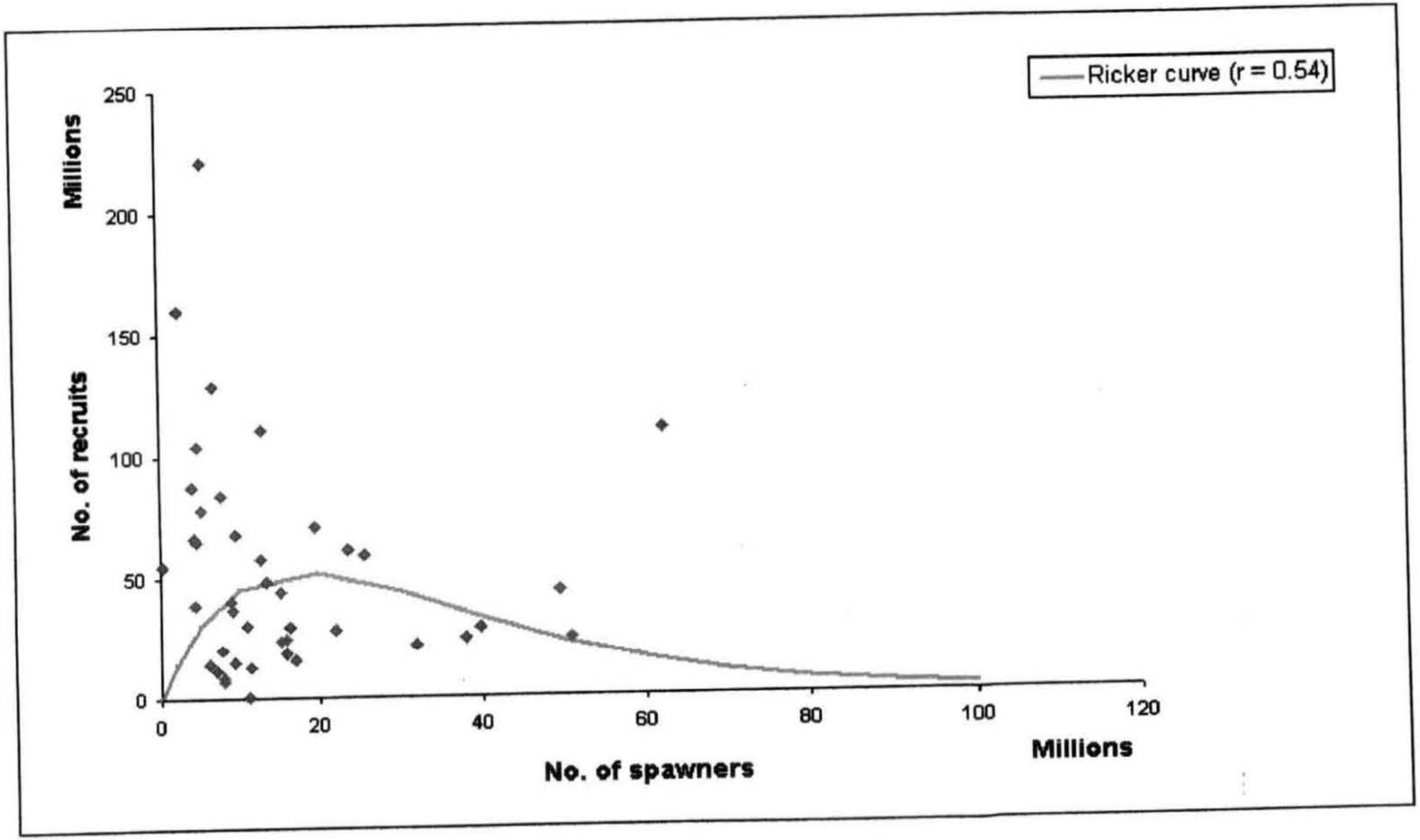

Fig. 47: Ricker curve fitted to the stock recruitment relationship (S - LnR/S)

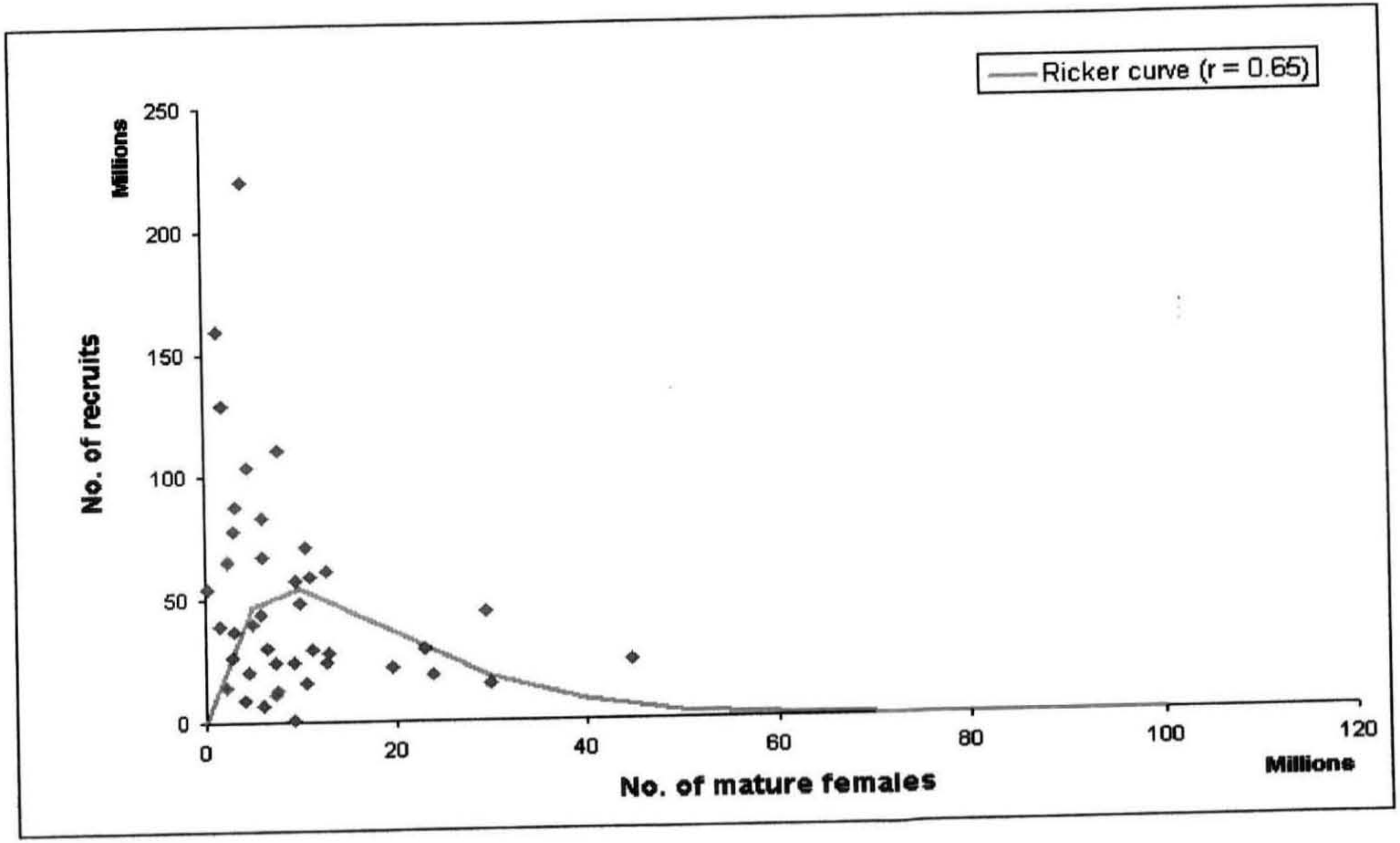

Fig. 48: Ricker curve fitted to the stock recruitment relationship (S' - LnR/S')

5. DISCUSSION

Metapenaeus affinis is distributed from the Gulf of Oman to South India and Sri Lanka and in the east extends as far as the Philippines and the Taiwan Island. It forms important fishery off Kuwait, Bahrain, Pakistan and Sri Lanka. Along the Indian coast it is the most important commercial species of the genus *Metapenaeus*, particularly near Mumbai (Bombay) (Holthuis and Miquel, 1984).

Penaeid prawn industry, being the backbone of the trawling industry in India, has been extensively reviewed and many have pointed out the need for management of this multi-species resource. Silas *et al.* (1984), describing the shrimp fishery in detail, stressed the need for regular monitoring of the biological and population characteristics of stocks of shrimps from different maritime States.

Fishery and resource characteristics of *M. affinis* have been reported from different regions of India. Ramamurthy *et al.* (1975) studied the fishery along Mangalore coast and reported that although it constituted only about one-tenth of the prawn catch of the region, it was of immense importance due to its large size and high export value. Later, while investigating the prawn resources along the northwest coast of India Ramamurthy (1994) reported that *M. affinis* was second or third important species in different years from 1978-85 and the fishery for the species showed a steady improvement in the region. Deshmukh *et al.* (2001) reported *M. affinis* to be the third most dominant penaeid prawn after *Parapenaeopsis stylifera* and *Solenocera crassicornis* landed by trawlers at Versova landing centre in Mumbai. Along the east coast of India, *M. affinis* formed the most dominant species in the Palk Bay in 1969 (James and Adolf, 1969). In 1973 it was reported to be the second most dominant species in the same region (Nandakumar, 1973). Later on, Maheshwarudu *et al.* (1996) reviewed the penaeid prawn fishery in the region and found that *M. affinis* formed only 1% of the total penaeid catch from the Palk Bay in 1986-87 and thereafter completely disappeared from the fishery. Among the penaeid prawn resources of the country it is perhaps first incidence of disappearance of an important species from the fishing ground, which has been attributed to by Maheshwarudu *et al.* (1996) to the ecological principle of succession of species. Although Maheshwarudu *et al.* (1996) did not offer any explanation for the cause of succession, it is perhaps excessive fishing pressure that exploited *M. affinis* beyond the level of 'commercial extinction' and the ecological void was replaced by the smaller, commercially unimportant species *Metapeneopsis stridulans*. This incidence explicitly shows the vulnerability of *M. affinis* to excessive fishing pressure and urgent need for management of its stock of much larger magnitude along the Mumbai coast, where it supports an important fishery.

5.1 Size Composition:

Size composition of harvested fishes in the catch is an indicator of the state of a fishery in an area. Changes in the size composition or the disappearance of larger size groups indicate overfishing of the species. Temporal and spatial composition of the juveniles also helps in determining the recruitment time and the area of their abundance.

Subrahmanyam (1963) while studying the bionomics of *M. affinis*, observed that prawns in the length range of 31-176 mm formed the fishery along Malabar Coast where smaller size groups were more abundant from April to August and larger ones in January and February. Ramamurthy *et al.* (1975) stated that smaller size groups (70 mm onwards) were observed to enter the fishery in March/April while November to February catches composed of sizes above 120 mm. In Pakistani waters Ayub and Ahmed (1992a) recorded males up to 151 mm and females up to 189 mm and observed that smaller size groups appear in April-May and again from October to December. In Mumbai waters, Mohamed (1967) reported appearance of juveniles in the month of September while Ramamurthy (1994) reported minimum mean lengths of the species during August to November along the Northwest coast of India.

In the present investigation, sizes ranging from 66 - 152 mm in males and 66 – 190 mm in females were encountered. The small sized prawns or juveniles ranging in size from 66 – 100 mm dominated the fishery during the post-monsoon months (August – December) in the shallow nearshore and nearshore areas, but their occurrence was sporadic in the offshore waters in the same period. Besides post monsoon months, the small sized prawns were also noticed in sizeable quantities in March in shallow nearshore waters, in April in nearshore waters and in June in shallow nearshore and offshore areas. The appearance of smaller prawns in most of the months in shallow nearshore and nearshore waters can be attributed to continuous spawning and recruitment. However, bulk of the small sized prawns was observed only in the monsoon and post monsoon months (August –December), which must be the major cohort contributing to the fishery.

5.2 Dimensional Relationships:

In order to compare the morphological characteristics of a species studied by different workers, or from different areas, it is important to have a mathematical expression describing the relationship between different dimensional measurements such as total length, carapace length, total weight, meat weight etc. These relationships are also important for the fishing industry for the conversions of "processed" weight from the "raw" weight of the material.

First report of length-weight relationship in penaeid prawns in Indian waters was given by George (1959). He found length-weight relationship of juveniles of *Metapenaeus monoceros* and gave a common exponent (b = 2.7603) for males and females. Rajyalakshmi (1961) in her study on *M. brevicornis*, did not get sex-wise difference in length-weight relationship but found different relationships for 0 - year group and older individuals and concluded that the species could be said to conform to the so-called cube law. But Rajyalakshmi (1981) later on reported separate total length-carapace length relationships in males, females and juveniles. Rao (1967) reported different length-weight relationships in males and females of both *Penaeus indicus* and *P. monodon* but got identical regression lines for the two sexes in both the species for total length-carapace length relationships. Thomas (1975) showed significant difference in length weight relationship of males and females of *P. semisulcatus*. Lalitha Devi (1987) gave separate relationships for males and females in *P. monodon, Metapenaeus monoceros* and *M. dobsoni* from Kakinada waters. Rao (1988) gave various dimensional relationships such as total length-total weight, total length-tail weight for *M. monoceros* and found them to be significantly different in the two sexes. He found the relationship between total length and carapace length to vary between juveniles and adults in both the sexes. He suggested that the difference in total length-carapace length relationships in juveniles and adults could be due to change in the growth of carapace at the time of maturity.

Sukumaran *et al.* (1993a) reported different length weight relationships for male and female *M. dobsoni* from different fishing grounds of India. Ramaseshaiah and Murthy (1997) found significantly different length-weight and total length-carapace length relationships in male and female *Metapenaeopsis barbata* and stated that upto 73 mm total length, males were found to be heavier that females, but 77 mm onwards females were heavier. Primavera *et al.* (1998) performed regression analysis on length-weight and total length-carapace length measurements of *P. monodon* of different life stages, sexes and sources and found that these relationships vary with life stage/age, source (cultured and wild) and sex. Patkar (2001) and Karnik (2002) found significant difference between males and females in various dimensional relationships in *Metapenaeus brevicornis* and *M. monoceros* respectively from Mumbai waters.

Dimensional relationships in *Metapenaeus affinis* were first reported by Mehendale (1959) who found the relationships between total length-standard length (distance between postorbital margin and tip of telson), total length-carapace length, standard length-carapace length, total length-total weight and standard length-total weight for males and females separately which showed very high degree of correlation. He further commented that the length-weight relationships were almost cubical ($W = 0.00000351\ L^{3.12}$ for males and $W = 0.000001153\ L^{3.37}$ for females). The results obtained in the present investigation were very close to these, the relationships being $W = 0.00000332$ and $L^{3.13}$ and $W = 0.00000139\ L^{3.32}$ for the two sexes in the same order. All the rest of the relationships also showed high degree of correlation.

Subrahmanyam (1963) found the relationships slightly less than cube value (2.78) for male and female *M. affinis* from Malabar Coast. Ramamurthy and Manickaraja (1978) found a linear relationship between tail length and total length and between carapace length and total length in the two sexes. Achuthankutty and Parulekar (1986) observed exponent of length-weight relationship greater than three in adults but smaller in juveniles suggesting lower rate of weight increase in juveniles as compared to the adults. Various morphometric relationships in male and female *M. affinis* obtained from the Arabian Gulf were given by Farmer (1986). The exponent of carapace length-total weight relationship was found to be less than 3 in males as well as in females. The relationships obtained were: $W = 0.0006736\ L^{2.97}$ for males and $W = 0.0007728\ L^{2.903}$ for females.

5.3 Length-at-Maturity:

The onset of sexual maturity in a species has been described in two ways, *viz.*, as the minimum size at which an animal is observed to be in mature condition and the smallest size at which at least 50% of the animals have attained maturity. The minimum size at maturity does not describe the maturation and spawning in a population since it could refer to the first maturity attained by a stray individual prawn. The size at which the population attains maturity (or 50% of the animals sampled over a period of time), also called the size of massive maturation (Rikhter and Efanov, 1976), is useful in throwing light on the fluctuations, breeding migrations and status of the fishery in a species (Kagwade, 1980).

Size at maturity in *M. affinis* has mostly been described in terms of minimum size at maturity. Mehendale (1959) recorded stage II and III ovaries from prawns between 101-110 mm and stage IV and spent ovaries between 111-120 mm sized prawns. From these observations he suggested that the size at maturity of *M. affinis* should be between 111-120 mm. Menon (1957) and Subrahmanyam (1963) mentioned that sexual maturity is reached in *M. affinis* at a total length of about 120 mm.

Ramamurthy *et al.* (1975) reported the smallest mature male to be 93 mm in length. George and Rao (1968) in their study of the external genitalia in some penaeid prawns noted that 50% of males had their petasmal endopodites fused at 71.6 mm. But, mere joining of petasmal endopodites would indicate only physical maturity. The ability to produce spermatophores or the physiological maturity together with physical maturity should be the correct index of sexual maturity of male prawns. In the present investigation, males with united petasma and clearly visible spermatophores were considered as mature and their size at 50% was 87 mm.

In the case of females of *M. affinis*, it is interesting to note that although Rao (1968) noticed the smallest mature female to measure 96 mm, he estimated minimum size at first sexual maturity as 88.6 mm by extrapolation. Ramamurthy *et al.* (1975) reported the smallest mature female to be 98 mm and estimated the length at maturity as 116 mm. Mathews (1989) reported from Kuwait waters that the smallest mature females was 18 mm in carapace length and found 50% of the prawns to be mature at 40 mm carapace length, which when converted by the expression given by Farmer (1986) were found to be 82 mm and 155 mm in total length respectively. In Pakistani waters the smallest female with ripe ovaries was 106 mm in size (Ayub and Ahmed, 1992b).

In the present study, the smallest mature females in the shallow nearshore waters and offshore waters were 93 mm and the same in the nearshore waters was 103 mm in length. The lengths at 50% maturity for the females were found to be different in the three fishing zones; 114 mm in the shallow nearshore waters, 104 mm in the nearshore waters and 129 mm in the offshore waters. But on pooling the samples from all the three fishing zones, it was seen that the 50% females attain maturity when they reach 114 mm length. This length at maturity is very close to 116 mm estimated by Ramamurthy *et al.*(1975) and also within the range 111-120 mm given by Mehendale (1959).

Beverton and Holt (1957) and Longhurst and Pauly (1987) opined that the ratio of length at 50% maturity and the asymptotic length (L_m/L_∞) usually ranges between 0.4 - 0.5 for tunas and 0.6 - 0.7 for the clupeids. It is usually smaller in large fishes and higher in small fishes, and is remarkably constant within families comprising fish of approximately similar dimensions. The ratio L_m/L_∞ in the case *M. affinis* is 0.54 and 0.55 for the males and females respectively. With the parameters reported by Karnik (2002) in the related species *M. monoceros*, the ratio works out to 0.51 and 0.52 for the two sexes which are very close to *M. affinis* within the genus *Metapenaeus*.

5.4 Monthwise Maturity Distribution:

Garcia (1985) stated that in penaeid prawns although spawning is more or less continuous at population level, very often they exhibit seasonal variations with one or two peaks per year. The double peak spawning pattern has been reported in many species *e.g. Penaeus latisulcatus* (Penn, 1980); *P. longistylus* (Courtney and Dredge, 1988). However, prolonged breeding season has been also reported for Indian species by Rajyalakshmi (1981) in the case of *Metapenaeus brevicornis* and by Rao (1989) for *M. monoceros*.

In the present study, mature females were noticed round the year, which suggests that the species breeds continuously. But, it was observed that spawning activity was more intense in certain months. In shallow nearshore waters, large proportions of females were in mature condition in April and again in September – October. Similarly, in nearshore waters the mature and ripe females peaked during March - May and in September. In the offshore waters they peaked during February - April and again in October – November. This shows two spawning peaks for *M. affinis* in

Mumbai waters, one in pre-monsoon (March - April) and the other in post-monsoon (September – November) months.

George (1961) observed October – December spawning of the species along the Cochin coast and Subrahmanyam (1963) observed the species to spawn from January to March along Malabar Coast. Rao (1968) reported the species to breed from October to March along the Southwest coast of India while Ramamurthy *et al* (1975) stated that the species exhibits protracted breeding from November to March along the Mangalore coast. But in Malaysian waters Hall (1962) reported two breeding seasons namely, May –June and October – December. In Kuwait waters too, Mathews (1989) observed two peaks of ripe females, a major one from March to July and a minor one during September – October. Ayub and Ahmed (1992b) also reported two spawning peaks in Pakistani waters, a major peak in February-March and a minor one in October.

In Mumbai waters Mehendale (1959) observed high percentage of mature females during April to July and again in November – December from the samples collected from *dol* nets operated in inshore and nearshore waters in Mumbai. Similarly, Shaikhmahmud and Tembe (1960) found two breeding peaks in October and May - June. Later, based on the samples obtained from trawlers operating off Mumbai, Mohamed (1967) reported intense spawning activity of the species during December - February and again in June – August. The present observation is in accordance with these with two breeding peaks for *M. affinis* in Mumbai waters.

Presence of two spawning peaks is further supported by the larval abundance of the species. Goswami *et al.*(1977) studied larval abundance of penaeid prawns during January to May 1972 along the central west

(Goa) coast of India and reported two peaks in the abundance of larvae of *M. affinis*, a small one in February and a larger peak in May. Achuthankutty and Nair (1983) also reported higher abundance of *M. affinis* larvae in pre-monsoon and post- monsoon seasons in the Mandovi estuary in Goa. In Pakistani waters also Ayub and Ahmed (1992a) observed two recruitment peaks of juveniles during April – May and again in October - December.

5.5 Spawning And Nursery Grounds

Shaikhmahmud and Tembe (1960) observed that there were indications that *M. affinis* preferred areas of soft mud, rich plankton and shallow coastal waters for mating and spawning. Similarly, Hall (1962) reported that in Malaysian waters the species breeds close to inshore areas. But, Subrahmanyam (1963) studying the breeding of the species along the southwest coast of India observed that the species moves to offshore areas for spawning. Studies at Cochin by George *et al.* (1963) indicated that the species could be breeding in 27-45 m deep waters. In the present study, mature females were noticed in varying proportions in shallow nearshore waters, nearshore waters and in offshore waters. Increasing percentage of mature females in different size groups in the three zones suggests that smaller prawns maturing for the first time move from shallow nearshore waters to nearshore waters and may move further to offshore waters. But those in the offshore waters undergo two or more spawnings and then return to shallow nearshore waters to spawn again. This suggests that the species spawns even in waters very close to the shore unlike most of the penaeid prawns which undertake obligatory spawning migrations to deeper waters and to never return.

Goswami *et al.* (1977) and George (1970) pointed out that occurrence of post-larvae and juveniles of the species in estuaries and backwaters was not significant. Longhurst and Pauly (1987) also pointed out that *M. affinis* and *Parapenaeopsis stylifera* are two principal species in Indian waters that do not use estuarine regions for their juvenile development. This suggests that inshore and estuarine waters are not essential nursery areas for the species to complete its life-cycle, unlike those belonging to the genus *Penaeus*. However, abundance of smaller sized, juvenile prawns in shallow nearshore waters observed in the present study support the view that shallow nearshore waters are their nursery areas from where they are recruited to the offshore fishing grounds. Bishop and Khan (1991) also observed that in Kuwait shallow coastal waters and marshes (1-2 m depth) served as the nursery area for the species as they offered protection to the juvenile prawns from their predators.

5.6 Spawning Periodicity:

Hickling and Rutenberg (1936) developed a hypothesis that investigation of a nearly ripe ovary may provide information on the spawning habits of fishes. Presence of ova intermediate to small immature ova and big ripe ones suggests the possibility of protracted spawning during the spawning period. But as De Jong (1940) pointed out, investigation of a few ovaries may reveal the spawning habit of individual animals, it does not indicate the periodicity of spawning in a species as a whole. Investigation of ovaries of individual animals provides information on whether the animal sheds all its mature eggs in a single batch or more, which coupled with information on the time taken for a set of eggs to mature and the distribution of mature females in the population, is used to determine the spawning periodicity and spawning season of the species.

In Indian penaeid prawns ova diameter studies have been used to determine the spawning periodicity of the prawn by many workers

(Shaikhmahmud and Tembe, 1960; Rao, 1968; Thomas, 1974; Nalini, 1976; Rao, 1989).

In the present study, the ova diameter frequency polygons in ripe ovaries showed only one mode of large mature ova in all the nine specimens examined. This suggests that all the mature ova are shed in a single batch by a mature prawn. Rao (1968) also suggested that the spawning in *M. affinis* is probably restricted to a short and definite period as indicated by the presence of only two groups of eggs in a mature ovary, the immature stock and the mature stock, which are sharply separated from each other. Later, Thomas *et al.* (1974) confirmed this by their laboratory experiments on spawning and rearing of *M. affinis*. They observed that most of the eggs in the ovary were shed in a very short period. Mehendale (1959) reported that it was not possible to get a correct picture of ova diameter frequency in case of *M. affinis* as eggs were not symmetrical and there was a large overlap of diameter of different stages of ova. But, by histological study of the ovaries he determined that only immature stock and mature eggs were present in ripe ovaries and that all the eggs were shed in a single batch.

Single peak of mature eggs has also been observed in *Metapenaeus monoceros* (Nalini, 1976 and Rao, 1989; Nandakumar, 2001), *Penaeus semisulcatus* (Thomas, 1974) and in *Parapenaeopsis stylifera* (Shaikhmahmud and Tembe, 1960). However, as the maturation in penaeid prawns is a continuous process and spawning period is very short, none of the ova-diameter studies help in knowing the number of spawning a penaeid prawn exhibits in its lifetime.

Rao (1968) used progression of modes of mature females in different penaeid prawns but did not observe any definite spawning pattern in the case of *M. affinis* because he encountered very few larger mature females and progression of modes could not be traced. However, he suggested the possibility that the prawns spawn more than once in their lifetime. In the present study, presence of modes at five size classes in a month suggests the possibility that a prawn spawns five times during its lifespan. Progression of modes in consecutive months in smaller size groups, 114 – 160 mm, suggested that they remature in about a month and spawn again. Larger prawns (> 170 mm) could be spawning at a longer interval of time *i.e.* once every two months, as indicated by the progression of mode at 173 mm in December to 178 mm in February and to 183 mm in April. Rao (1989) also suggested 4-5 spawnings in the lifetime of *M. monoceros* based on the presence of 4-5 modes of ripe females in different years.

5.7 Sex Ratio:

Investigations on the sex ratio of a species help in understanding the segregated migrations of the two sexes during maturation and spawning. In the case of penaeid prawns, changes in sex ratio influenced by movements and migrations for maturation and spawning were shown for the first time by Lindner and Anderson (1956) and subsequently by many others. In Indian waters Menon (1957) and George and Rao (1967) gave detailed account of the same.

First report on the sex ratio in *M. affinis* and other species of penaeid prawns in Indian waters was given by Menon (1957). He studied the sex ratio separately for immature (< 120 mm total length) and mature prawns and found that in the immature prawns the sexes were almost evenly represented whereas among the older prawns females outnumbered by a margin of 11.6%. Subsequently, Mehendale (1959) reported predomination of females of the species over males in Bombay waters by a margin of 12.8% when all the sizes were pooled together. The sex ratio in different sizes however, showed that males *outnumbered by a* margin of 2.9% in sizes below 100 mm, which increased to 15.6% in 101 – 120 mm size group. From this he suggested that females, which attain maturity at this size, might be migrating to deeper waters for spawning. In the sizes between 121 – 140 mm, females dominated by a margin of 15.6% and by 66.2% in higher sizes. He further suggested the possibility that the females remain in deeper waters and probably return only after two or three spawnings.

George *et al.* (1963) while working on the same species in Cochin waters found predominance of males in the smaller size groups and suggested the possibility of breeding movements. Subrahmanyam (1963) and Ramamurthy *et al.* (1975) also found dominance of females at Calicut and Mangalore respectively. However, George and Rao (1967) reported that offshore trawl catches from Cochin waters did not show significant difference in sex ratio and suggested absence of any segregated migration for breeding. From Kuwait waters Mathews (1989) reported that the sex ratio was in favour of males in smaller size groups and the reverse in larger prawns. This pattern has been generalized by him by stating that it is typical of a species that has a larger value of L_∞ for females than males.

In the present investigation, males and females of the species were evenly distributed up to a size of 100 mm but between 100 – 125 mm the males outnumbered the females in shallow nearshore and nearshore waters. In sizes beyond 125 mm females dominated in all the fishing zones. This could be attributed to migration of females to offshore waters.

Shaikhmahmud and Tembe (1960) reported females of *M. affinis* in Bombay waters to dominate in all the months, especially in the months of

October, November, December, and April, May and June when greater number of maturing and mature females were encountered.

In the present investigation, monthwise sex ratio indicated that in the shallow nearshore waters the two sexes were evenly distributed in the months of April, June, September, October and December, and in the nearshore waters the sex ratio was not significantly different in the months of April, August, September, October and November. But, in the offshore waters, females outnumbered the males in all the months. The proportion of mature and ripe females in the same months was also higher in the offshore waters. Thus, even distribution of the two sexes in certain months in shallow nearshore and nearshore waters and significant dominance of females coupled with high proportion of mature females in offshore waters clearly indicate migration of females for spawning from inshore to offshore waters.

Ripe females were noticed in shallow nearshore waters in April and November. This could be due to formation of steep temperature gradients in those months. Joseph and Singh (2002) showed that April and November are the transition months when changes in surface water temperature are as high as 3 - 5°C off Versova, where fishing is carried out in shallow nearshore waters by the hand operated trawlers. Garcia (1985) stated that spawning peaks of penaeid prawns occur frequently during transition periods which separate cool and warm seasons and are characterized by certain hydrological and climatological features such as rising or falling temperature, low current velocity, wind speed as well as high rainfall and severe drop in salinity. Therefore, presence of mature females in shallow nearshore waters could be due to temperature gradient, which triggered maturation of these females despite of shallow water conditions.

5.8 Fecundity:

Tropical penaeid prawns are known to be highly fecund organisms laying 50,000 – 1,300,000 eggs depending on size and species (Garcia, 1988). The individual prawns are partial spawners and can lay several batches of eggs every year (Garcia, 1985).

In the present investigation, the fecundity of *M. affinis* varied from 58,261 ova in a female of 104 mm length to 4,48,146 ova in a female of 162 mm length. Rao (1968) estimated the fecundity to vary between 88,000 (TL 95 mm) to 3,63,000 ova (TL 160 mm). In the related species, Rao (1989) estimated the fecundity of *M. monoceros* to range from 53,684 (in 113 mm female) to 4,16,273 ova (in 181 mm female).

On studying the relationship between total length/total weight/ovary weight and fecundity, it was observed that fecundity showed better correlation with weight of ovary. The relationship was however exponential, which seems logical since the number of ova contained in the ovary would depend on the volume of the ovary. Number of ova also showed fairly good exponential relationship with total length and total weight of the prawn. Rao (1968) also reported good exponential correlations between fecundity and ovary weight in the case of *M. affinis, M. dobsoni, Penaeus indicus*, and *Parapenaeopsis stylifera*. Good exponential correlation between fecundity and size of the prawn has been reported by various workers (Nalini 1976, Penn 1980, Sukumaran and Rajan 1981, Crocos and Kerr 1983 and Crocos 1987a). Rao (1989) observed fecundity to be directly proportional to total length, total weight and ovary weight. But Thomas (1974) did not get any correlation between the size of the prawn and fecundity in *Penaeus semisulcatus*. Velázquez and Garcia (2000) found gonad weight a more precise indicator of fecundity as compared to total length or total weight. They suggested that the variability of fecundity based on weight could be related to the fact that shrimps are partial and multiple spawners. In the present study, fecundity showed a good exponential correlation with total weight ($r = 0.85$), which may suggest that the prawn sheds all the eggs in a single spawning and every time the ovary re-matures the number of ova produced is proportional to the weight of the prawn.

5.9 Population Fecundity Index:

Population fecundity is the sum of fecundities of all the females in the population (Bagenal, 1978). Penn (1980) suggested that in penaeid prawns, population fecundity may be used in combination with data on spawning frequency for investigation of spawning season. Earlier work on the spawning season of penaeid prawns in Indian waters is based on the proportion of mature females in a particular month (Ramamurthy *et al*, 1975; Rajyalakshmi, 1981; Rao, 1989; Sukumaran *et al*, 1993b)). Although proportion of mature females gives the months in which the maximum percentage of females spawn, it does not give the quantum of recruitment that arises out of such spawning, which is of importance to the annual stock generation of the species in the fishery. Garcia (1985) also commented that the widely used percentage of mature females is a biased index of population reproduction and must be combined with an index of adult abundance and with fecundity at size data.

Penn (1980) studied variations in the population fecundity index in *Penaeus latisulcatus* and suggested two spawning peaks for the prawn. Crocos and Kerr (1983) used population fecundity index to determine spawning frequency and spawning area of *P. merguiensis*. They found that in the southeastern Gulf of Carpentaria, where, although proportion of spawners was high in spring, the egg production in that season was considerably lower than in autumn, when in spite of low proportion of spawners, egg production was higher due to large population of adult females. Crocos (1987a) and (Crocos, 1987b) used population fecundity index to determine the spawning pattern in *Penaeus semisulcatus* and *P. esculentus* respectively.

Courtney and Dredge (1988) observed two peaks of spawner abundance in *P. longistylus* and *P. latisulcatus* but the same was not reflected in the population fecundity indices of the two species due to changes in the total number of adult females.

In the present investigation, even though maximum proportion of mature females was observed in the months of April and November, the egg production was the highest in September, which is attributed to high abundance of adult females in the month of September. Crocos and Velde (1995) also found population fecundity index to be a function of the complex interactions of the abundance and size structure of the females and the proportion of spawners in case of *Penaeus semisulcatus*.

5.10 Age And Growth:

Gulland and Rothschild (1984) stated that penaeid prawns grow rapidly and very generally live only about one year. Results obtained in the present study also indicated that *M. affinis* is a fast growing species with a short life span of about one and a half years. The asymptotic length (L_∞) is 162 mm and 204.5 mm and the annual growth coefficient (K) is 2.25 and 1.9 for male and female respectively. The growth coefficient indices (φ') are 2.7712 and 2.9024 for male and female respectively.

Most of the previous work on age and growth of *M. affinis* suggested that it is a slow growing species with life span of about three years. Subrahmanyam (1963) attributed three years or more life span to the species, with the male growing up to 101 – 105 mm, 131 – 135 mm and 155 mm at the end of first, second and third years respectively and female growing up to 111 – 115 mm, 151 – 155 mm and 176 mm at the end of same years respectively. Mohamed (1967) described the growth in smaller sizes and stated that they grow about 10 mm per month in the first year so as to attain 120 mm on completion of one year of life. Ramamurthy *et al* (1975) estimated L_∞ of male and female of the species as 174.3 mm and 188 mm respectively and K to be 0.84 and 0.72 respectively with a life span of three years. Pauly *et al.*(1984) utilized the length-frequency data of *M. affinis* from Mumbai during 1958 -59 reported by Mohamed (1967) and estimated L_∞ 175 mm and K 1.2 for the two sexes together. Achuthankutty and Parulekar (1986) estimated L_∞ 156.8 mm and 202.6 mm and annual K 1.73 and 0.89 for male and female respectively. Vibhasiri (1988) estimated the growth parameters as L_∞ 150 mm and 174 mm and K 0.85 and 0.84 for male and female respectively. Mathews (1989) reported slightly higher growth rate for the species with K values 1.09 and 1.22 for male and female respectively and L_∞ of 162.4 mm for male and 182.82 mm for female. Paralkar (1990), studying the species in Mumbai waters, estimated higher values of L_∞, 193.7 mm for male and 235.7 mm for female. But, the values of K estimated by her are 0.6 for male and 0.56 for female. Slow growth rate and long life span attributed to the species by these workers is unacceptable because tropical penaeid prawns are known to have a fast growth rate and short life span (Gulland and Rothschild, 1984 and Garcia, 1988).

In the present study it was noticed that young recruits (< 100 mm) enter the fishery in bulk in August – September when CPUE is the highest. The size distribution of these recruits showed modal sizes at 79 mm and 84 mm for males and females respectively. Enormous number or these small sized prawns caught by the trawlers during August – September suggests that they must be the recruits from heavy spawning that has taken place in April when 70 – 80% of females were in mature and ripe condition. If it is assumed that these females have spawned in the middle of April, the young recruits must be four months old by August. Sizes attained by these recruits in Mumbai waters, calculated using growth parameters given by Pauly *et al.* (1984), Paralkar (1990) and the present study showed (Table 53) that those obtained by the present estimates are the closest to the sizes of the recruits appearing in August.

Various estimates of L_∞ in the range of 174 – 188 mm obtained in all the previous studies are too low since many specimens in the size range of 186 – 190 mm were collected during the present study. Paralkar's (1990) estimate of L_∞, 235 in female, at a very low growth rate of 0.56 gives an improbably high age at that size.

Pauly *et al.* (1984) compared the growth patterns of various penaeid prawns by finding out growth performance indices (φ'). They found that the growth performance index of *M. affinis* falls in the same range as *Penaeus* spp., which are the fastest growing prawns. Thus, growth in *M. affinis* must be comparable to that of *Penaeus* spp.

Rao and Krishnamoorthy (1990) working on *M. monoceros*, a species closely related to *M. affinis*, estimated L_∞ to be 178.4 mm and 207.3 mm in male and female respectively and estimated K as 1.68 and 1.62 for the two sexes in that order. These results are comparable to the present study. Growth performance indices, φ', of *M. monoceros* calculated by using Rao and Krishnamoorthi's (1990) growth parameters and Rao's (1988) length – weight relationship were 2.7280 in male and 2.8427 in female which are also quite close to the φ' of *M. affinis* estimated in the present study.

All these evidences clearly suggest that the slow growth rate and long life span estimated for *M. affinis* in the previous studies are improbable and the results obtained in the present study describe the growth more appropriately.

Table 53: Monthwise size of male and female *M. affinis* using different growth parameter estimates

AUTHOR	**Pauly *et al***	**PARALKAR**		**PRESENT STUDY**	
AGE IN MONTHS	Both sexes	Male	Female	Male	Female
3	45.35	26.98	30.79	69.69	77.32
4	57.69	35.11	40.13	85.48	95.95
5	68.86	42.85	49.05	98.56	111.84
6	78.96	50.2	57.56	109.41	125.41
7	88.1	57.2	65.68	118.4	136.99
8	96.37	63.86	73.43	125.85	146.88
9	103.85	70.19	80.83	132.03	155.32
12	122.29	83.39	101.07	144.92	173.91

5.11 Mortality:

Garcia and Le Reste (1981) suggested that with life span of about two years in penaeid prawns, natural mortality coefficient 'M' would be 2 - 3 per year. The natural mortality of *M. affinis* estimated by various methods in the present investigation ranged between 3.15 – 3.8 for males and 2.64 – 3.29 for females on annual basis. The estimates obtained by Pauly's empirical formula (3.6 year $^{-1}$ in male and 3.05 year $^{-1}$ in female) gave M/K ratio of 1.6 and 1.59 for the two sexes respectively. Since these estimates were greater than 1.5 they were considered to be more appropriate as Garcia and Le Reste (1981) suggested that for penaeid prawns this ratio should lie between 1.5 and 2.5.

From the data presented by Mohamed (1967) for *M. affinis* from Mumbai waters, Pauly *et al.* (1984) obtained natural mortality as 2.29 on annual basis. Mathews (1989) estimated mean annual M for male and female *M. affinis* as 2.09 in Kuwaiti waters while Paralkar (1990) obtained the same as 1.09 for males and 1.11 for females in Mumbai waters. Since Pauly's empirical formula (1980a) incorporates both L_∞ and K, the lower estimates of M obtained by Pauly *et al.* (1984), Mathews (1989) and Paralkar (1990) are largely due to lower growth coefficients considered by them for the species. Vibhasiri (1988) assumed a value of 3 from the Gulf of Thailand, which is comparable to the present estimates.

Total mortality coefficients estimated in the present study were 13 and 7 for males and females respectively, which may appear higher. However, if their exploitation ratios are considered (E = 0.72 and 0.58 for males and females respectively) and the fact that most of the penaeid prawns are heavily exploited in Mumbai waters (CMFRI, 2000), the present values are not over-estimates. The disparity in the exploitation rate in male and female prawn could be due to shorter life span of males and also because of significant difference in sex ratio.

Ramamurthy *et al.* (1975) reported annual fishing mortality to vary from 0.64 in 1965-66 to 6.39 in 1967-68 with an average of 3.76 in case of male and the same to vary from 0.77 to 4.33 with an average of 2.5 along the Mangalore coast. Since exploitation of penaeid prawns has increased remarkably in the last 30 years, the fishing mortality can be expected to be much higher at present.

Based on the data presented by Mohamed (1967), Pauly *et al.* (1984) estimated Z as 5.29 and F as 3.00 per year with an exploitation ratio of 0.57 in Mumbai in 1958-59. During 1959-63 the trawl fishery was in Mumbai was in its infancy, and the artisanal *dol* net fishery never targeted the penaeid prawns (Raje and Deshmukh, 1989), so the exploitation ratio calculated by Pauly *et al.* (1984) is clearly an overestimate. At present there are about 6000 trawlers in Maharashtra of which more than half operate off Mumbai targeting penaeid prawns, therefore exploitation ratio must be higher. Paralkar (1990) reported Z to be 4.57 in male and 4.12 in female in late eighties in Mumbai waters with an exploitation ratio of 0.76 and 0.73 respectively. The high values of exploitation ratio obtained by her were mainly due to very low natural mortality coefficients.

All the previous studies estimated very low growth rate and long life span of *M. affinis* and hence low natural and total mortality. At a growth rate of 2.25 and 1.91 in male and female respectively, and a life span of less than two years, and a high level of exploitation due to high market value, the mortality estimates obtained in the present investigation in Mumbai waters appear to be more reasonable.

5.12 Stock Assessment:

In the present investigation, the sizes at capture estimated by selection curve of the trawl net at 50% (L_{50}) were found be 114 mm for males and 115 mm for females. The L_{50} is much higher than the length-at-maturity for males and almost the same (114 mm) in females. In Kuwaiti waters Mohammed (1995) reported L_c of 17.6 mm and 24.4 mm carapace lengths in male and female respectively. Using total length-carapace length relationship given by Farmer (1986) the corresponding total lengths were 74.7 mm and 103.4 mm.

Length based cohort analysis indicated a standing stock biomass of 170.42 tonnes of males and 473.37 tonnes of females in Mumbai waters. Total catch during the period under study was 443.45 tonnes of males and 1386.85 tonnes of females.

Yield per recruit analysis suggested that maximum yield per recruit is possible at exploitation ratio of 0.677 in males, but the present exploitation ratio (0.72) is higher. Therefore, fishing effort needs to be reduced marginally by 6.3%. If the fishing effort is reduced, the biomass per recruit will also improve to reach 20% of the unexploited stock. In case of females maximum yield is possible at the exploitation ratio of 0.638 (present is 0.58), which suggests that fishing effort can be increased by 10% of the present level, which will also bring biomass per recruit to 20% of the unexploited state. Goodyear (1989) pointed out that critical level of biomass per recruit of mature females (B_m/R) should be 20% of the unfished B/R to prevent recruitment overfishing and for the sustenance of the stock. The present study showed that proportion of adult females (above the size at maturity *i.e.* 114 mm) by weight was 0.93, which on multiplying the B/R value gave B_m/R 21% of the unfished population. It is because of this B_m/R, which is above the critical level that the stock of the species is not under immediate threat of recruitment overfishing. Mathews (1991) analysed the fishery for *M. affinis* and observed that B_m/R was only 1% of the unfished biomass, which he correlated to recruitment overfishing in Malaysian waters.

Yield isopleth indicated that maximum yield is possible if the length at capture is reduced from 113 mm to 81 mm, i.e., L_{50}/L_∞ is reduced from 0.7 to 0.5, and the exploitation ratio is reduced from 0.72 to 0.67. Reducing the length at capture from the present level of 115 mm to 102 mm and increasing the exploitation ratio from 0.58 to 0.6 can achieve the same results in the case of females. But, the reduction in length at capture could be precarious especially in females, since the suggested L_c (103 mm) is much lower than the length at maturity (L_m = 114 mm) which would affect the reproductive potential of the stock. Exploitation of the same species in Malaysian waters with L_c of 95 mm and L_m of 125 mm, the stock suffered recruitment overfishing (Mathews, 1991). Further, Thompson and Bell yield-stock prediction model suggested that the maximum possible yield is only marginally higher (by 20 t) which would require 80% increase in the fishing effort. However, by increasing the fishing effort the economic yield would decrease. Maximum economic yield is possible only by reducing the effort by 20% of the present fishing effort.

5.13 Stock Recruitment Relationship:

The problem of relating the size of parent stock in fish to the number of progeny entering a fishery was first examined in detail by Ricker (1954) based on which he gave a model. It is a dome shaped curve, describing the situation where recruitment reaches a maximum and then decreases at high stock levels due to density dependent control mechanisms such as cannibalism, competition for limited resources etc.

Beverton and Holt (1957) gave another model, which suggests that recruitment approaches an asymptote at high stock levels. Shepherd (1982) suggested a third model that integrates the shape of both the models.

Garcia and Le Reste (1981) in their review on biology and dynamics of penaeids noted that there is no clear relationship between stock and recruitment within a range of reasonable levels of exploitation and that recruitment can be considered to depend on the environment only. They also noted that according to Bakun and Parrish (1981) if nurseries have a limited and relatively constant biological capacity, the Beverton and Holt type relationship is the most likely one. Garcia and Le Reste (1981) also suggested that due to high fecundity in penaeids, their stock recruitment relationship is Ricker's dome shaped type, which is typical of high fecundity animals.

Subsequently, Garcia (1983) reviewed the available evidence on stock recruitment relationships in shrimps and on the existence of natural or man-induced environmentally driven changes in stock size of shrimps and opined that some of the relationships inferred could be artefacts or misrepresentations. Initial work on stock recruitment relationship of penaeid prawns was based on annual catch or catch per unit effort. Brunenmeister (1984) correlated annual catch per unit effort in year n+1 with the calculated number of survivors during the main spawning season in year n for *Penaeus aztecus* and *P. setiferus* and found significant correlations. She suggested that abundance in one year is related to the degree of exploitation and stock size in the previous year. This was considered as stock recruitment relationship by Rothschild and Parrack (1981).

Parrack (1981) found a stock recruitment relationship for *P. aztecus* in the Gulf of Mexico. The relationship was established between spawning stock estimated by monthly cohort analysis and the recruits three months later. These were then separated into spawning months. A nearly linear relationship was obtained with different slopes for different months. Garcia (1983) suggested that the seasonality observed in the slope of the curves could be due to the expected natural seasonal variations in survival from the egg to recruitment. Another reason pointed out for this seasonal variability was the method used for the estimation of spawning stock. All individuals of 8 months or older were taken as spawning stock, overlooking the fact that spawning activity is highly seasonal. In order to avoid this drawback in the present investigation, the relationship of the recruits was analysed with the total adult females and the total monthly mature females separately. It was observed that the correlation was better when the mature females alone were taken as the spawning stock. This seems logical since all the adult females are not mature and do not spawn. Only the mature ones spawn and contribute to egg production in that month. Furthermore, by taking only the mature female population, spawning season of the prawn is also incorporated into the model.

Boddeke (1982) analysed the monthly cohort data and found four different asymptotes for four areas and suggested that the area of the nursery ground area was the limiting factor for recruitment.

Rothschild and Parrack (1981) found only a weak relationship for *Penaeus setiferus* but a strong quasi-linear relationship for *P. aztecus* by taking the yearly catch per unit effort (in weight) in year n as an index of spawning stock and the highest monthly catch per unit effort (in numbers) for year n+1 as an index of subsequent recruitment. Morgan and Garcia (1982) found a quasi-linear relationship for *P. semisulcatus* in Kuwait waters in which spawning stock was measured as the average CPUE in a biological year n, which consisted of twelve months period starting at recruitment of the main cohort. Recruitment in year n+1 was calculated by dividing the annual catch Y_{n+1} by the yield per recruit $(Y/R)_{n+1}$.

Penn (1984) analysed the relationship between stock resilience to fishing and catchability and suggested that the decreases in annual yield observed in some stocks of medium and high catchability may be an indication that recruitment has been affected by fishing. He opined that although growth overfishing resulted in reduced yields, it could not be the major cause of decline in recruitment. He further suggested that environmental effects could explain short-term fluctuations in recruitment but not the long-term decline in yield.

Staples (1985) modeled the recruitment processes of *P. merguiensis* in the Gulf of Carpentaria in order to study the year-to-year fluctuations and downward trend in catches of the prawn. He suggested a multistage model, which described the stock recruitment relationships between four main life history stages of the prawn incorporating the combined effects of rainfall and juvenile numbers. The model suggested that in the fourteen-year study period, spawning levels and juvenile densities remained sufficiently high for rainfall to be the most important factor in determining the offshore catches.

Bauer and Lin (1994) suggested that a complex stock recruitment relationship exists in *Trachypenaeus similis* and *T. constrictus* based not only on spawning stock abundance but also on temperature and larval food supply.

The present investigation shows that stock of *Metapenaeus affinis* off Mumbai waters follows Ricker's model of stock recruitment relationship, which implies that although recruitment increases with increase in spawning stock up to about 20 million spawners, it would decrease subsequently at very high adult stock densities. This inference is plausible since *M. affinis* is a bottom dwelling prawn (Holthuis, 1980). For such benthic organisms competition for limited food and space becomes an important factor as density increases.

Maximum proportions of mature females were observed in the months of April and November and maximum recruitment in the post-monsoon months of August – September and to a smaller extent in March – April. Bulk of the recruitment was in the post-monsoon months, which is the result of heavy spawning in April. Although the population fecundity index indicated higher egg production in September, it did not result in major recruitment in January – February four months later. This points to the role played by environment in the growth and survival of larvae. *M. affinis* being almost a marine species and does not require low salinity conditions for post-larval development as seen from their near absence in inshore waters (George, 1970 and Goswami *et al*, 1977) and estuaries (Achuthankutty and Nair, 1983). Although Salman *et al.*(1991) observed migration of juveniles to low saline estuaries in Iraq, it would be possibly due to hypersaline conditions existing in the Gulf.

In the present investigation, relationship between number of mature females and corresponding recruits, fitted to Ricker model indicated that maximum recruitment is possible with 5 – 20 million mature females. In the spawning season, proportion of mature females in *M. affinis* ranged between 70 to 80%. Assuming that 75% of the total adult females mature during the spawning season, the total adult females required for ensuring good recruitment is 6.6 – 26.6 million. In order to obtain the highest recruitment, the number of mature females required is 10 million, which means a standing stock of 13 million adult females or a standing stock biomass of 193 t, for the sustenance and stock generation. Under the present fishing conditions the standing stock of the adult females is however, 297 t. It is perhaps due to this reason that despite steady increase in fishing effort the catch of the species has not declined to alarming levels in Mumbai waters. However, this does not imply that higher biomass of 297 t should be fished out to 193 t since fishery independent factors, which also influence the recruitment have not been taken into account in the present study. It is necessary to study the effect of environmental factors on spawning and recruitment of the prawn. Therefore, it is advisable to maintain spawning stock at the present level, which is higher than required, to absorb the fluctuations caused by the vagaries of the environment.

From the foregoing following suggestions are given for the sustainability of this fishery:

1. Since egg production during September-October does not contribute to significant recruitment three months later, the species can be fished hard in post-monsoon period.
2. The stock recruitment study showed that highest recruitment is possible with 13 million spawners or 193 tonnes of biomass of spawners.
3. Since peak spawning in April results in good recruitment in August-September, the spawning biomass of 193 tonnes of mature females needs to be maintained in offshore waters in pre-monsoon months of April-May.
4. Although the yield per recruit analysis suggested a reduction in length-at-capture, this is not advisable since it would result in a reduction of B_m/R below 20%. Therefore the size at capture should be maintained at the present level.

SUMMARY

The present study was undertaken to investigate the reproductive dynamics, including stock-recruitment relationship of *Metapenaeus affinis* (H. Milne Edwards, 1837) in Mumbai waters. *M. affinis* forms the third most important penaeid prawn in terms of abundance in Mumbai waters after *Parapenaeopsis stylifera* and *Solenocera crassicornis*. But in terms of value it fetches higher price in domestic as well as overseas market. It is exported as "medium brown". In the local market it is called "chaiti".

The catch landed by trawlers at New Ferry Wharf and by trawlers and hand-operated trawlers at Versova was examined for its biology and fishery characteristics. The samples represented catch from shallow nearshore (5 -10 m depth), nearshore (15 – 40 m depth) and offshore (up to 70 m depth) waters.

Males in the size range of 66 - 152 mm in total length and females in the size range of 66 - 190 mm were observed during the study period. Fishing season started in August-September after monsoon with the appearance of large number of recruits. Although small sized prawns were observed throughout the year, bulk of the recruitment was during this period and again, to a lesser extent, in March-April.

Length-weight relationships for the two sexes was determined by the linear regression of total lengths and total weights of 431 males in the size range of 66 –152 mm and 654 females in the size range of 69 –175 mm. The equations obtained were:

Male: $W = 0.000003323\ L^{3.13}$ $(r = 0.97)$

Female: $W = 0.000001395\ L^{3.32}$ $(r = 0.98)$

Length at maturity was estimated by King's (1995) method. Males with united petasma and clearly visible spermatophores in the terminal ampoules were considered as mature and at 87 mm 50% of the males were mature. Ovary was distinguished into five stages of maturity (as given by Rao, 1968) by macroscopic as well as microscopic examination and stage III and IV ovaries were considered as mature. Length at maturity was 114 mm.

Mature and spent ovaries were observed throughout the year indicating that the species is a continuous spawner. But the spawning activity was highest in April, and in October-November. Although the population as a whole is a continuous spawner, an individual female was found to shed all its mature eggs in a single batch. This was determined by ova diameter studies of ripe ovaries. In addition, progression of modal sizes of mature females suggested that a female would mature and spawn about five times during its lifetime.

The ovaries of 67 females, 102 – 162 mm in size, were examined and the fecundity was found to range from 0.58 lakh to 4.5 lakh eggs. Fecundity showed good exponential correlation with ovary weight.

Since population fecundity index was reported to be a better indicator of spawning season and spawning habit of a species (Penn, 1980 and Garcia, 1985) it was estimated for each month by pooling the total number of eggs produced by the mature females in each size class in the three fishing areas. Population fecundity index or the total egg production by the population was highest in September although proportion of mature females was maximum in April. Although proportion of mature females was small in September, the overall abundance of the species in numbers was so large that the total egg production of the month masked the PFI of rest of the months including that of April when majority of the females were in mature condition. Greater abundance of females, despite of small fraction of mature ones was responsible for such high PFI in September. But this high egg production in September did not result in high recruitment of prawns 3 – 4 months later. Bulk of the recruitment in August-September, resulting from April spawning indicated better survival of larvae in summer and post larvae and juveniles in monsoon months.

Age and growth of the two sexes of the prawn was studied by various methods. Monthwise length frequencies from the three fishing areas were pooled to study growth and mortality of the species. The growth was studied by analysis of progression of modes and the von Bertalanffy growth parameters asymptotic length (L_∞) and growth coefficient (K) were estimated by Gulland and Holt plot. VBGF parameters were also estimated by various methods using FAO-ICLARM Stock Assessment Tools (FiSAT). The estimated VBGF parameters were:

Male: L_∞ = 162 mm	Female: L_∞ = 204.5 mm
K = 2.25	K = 1.91
$t_0 = 0$	$t_0 = 0$

The species was found to be a short lived one with a fast growth rate like prawns of the species *Penaeus*. Life span was about one and a half years. Juveniles were recruited to the fishery when three months old and age at maturity of females was about five months.

Mortality rates and exploitation of the species in the Mumbai waters were estimated by various methods and the estimates were:

Male Female

Total mortality:	13.06 $year^{-1}$	7.18 $year^{-1}$
Natural mortality:	3.62 $year^{-1}$	3.05 $year^{-1}$
Fishing mortality:	9.44 $year^{-1}$	4.13 $year^{-1}$
Exploitation rate:	0.72	0.58

Length at capture by the selection curve method was 113 mm for males and 115 mm for females.

Length based cohort analysis indicated a standing stock biomass of 170.42 tonnes of males and 473.37 tonnes of females in Mumbai waters. Total catch during the period under study was 443.45 tonnes for males and 1386.85 tonnes for females.

Relative yield per recruit and relative biomass per recruit analysis suggested possibility of increase in fishing effort and reductions in length at capture, but Thompson and Bell yield-stock prediction model indicated decrease in value of the catch with increase in fishing effort.

In the present investigation stock recruitment relationship was established on monthly cohort basis. Monthly length frequency data for four years was used and numbers in sea estimated by length based cohort analysis. Number of prawns larger than length at maturity was considered as the spawning stock and the number of juveniles three months later was taken as recruitment. Stock recruitment relationship was also analysed by taking the number of mature females in a month as the spawning stock. Ricker model could be fitted to the relationship with a correlation coefficient 0.65. This indicated that initially recruitment increased with increasing stock levels but at large stock levels density dependent control mechanisms came into play and recruitment declined. Maximum recruitment was observed at stock size of 10 million spawners.

Following suggestions have emerged from the present investigation:

1. Since egg production during September-October does not contribute to significant recruitment three months later, the species can be fished hard in post-monsoon period.
2. The stock recruitment study showed that highest recruitment is possible with 13 million spawners or 193 tonnes of biomass of spawners.
3. Since peak spawning in April results in good recruitment in August-September, the spawning biomass of 193 tonnes of mature females needs to be maintained in offshore waters in pre-monsoon months of April-May.
4. Although the yield per recruit analysis suggested a reduction in length-at-capture, this is not advisable since it would result in a reduction of B_m/R below 20%. Therefore the size at capture should be maintained at the present level.

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